



THE CHEMISTRY OF FOODS AND NUTRITION. I.*

THE COMPOSITION OF OUR BODIES AND OUR FOOD.

"Half the struggle of life is a struggle for food."—EDWARD ATKINSON.

"I have come to the conclusion that more than half the disease which embitters the middle and latter part of life is due to avoidable errors in diet . . . and that more mischief in the form of actual disease, of impaired vigor, and of shortened life, accrues to civilized man . . . in England and throughout central Europe from erroneous habits of eating than from the habitual use of alcoholic drink, considerable as I know that evil to be."—SIR HENRY THOMPSON.

"If we will care for men's souls most effectively, we must care for their bodies also."—BISHOP R. S. FOSTER.



WHAT proportion of the cost of living might be saved by better economy of food; how dietary errors compare in harmfulness with the use of alcohol; whether, as some urge, our next great reform is to be in our dietetics; and to

what extent the spread of the gospel and the perfection of its fruit are dependent upon the food-supply, are questions which it is not my present purpose to discuss. I have quoted the foregoing statements, however, because they come with authority, and because, starting from the widely different standpoints of the economist, the physician, and the divine, the conclusions tally perfectly with those of some studies of my own.

Mr. Atkinson cites statistics to show that all but the very few who are especially well-to-do, in this country as in Europe, must expend half or more than half of their earnings for their food; calls attention to our wastefulness, and urges the need of better economy in the purchase and use of food-materials. The error which Sir Henry Thompson most seriously deplores is over-eating. "It is a failure to understand, first, the importance of preserving a near equality between the supply of nutriment to the body and the expenditure produced by the activity of the latter; and, secondly, ignorance of the method of attaining this object in practice, which gives rise to the various forms of disease calculated to embitter and shorten life." Bishop Foster, considering, on the one hand, the destitution that prevails, both at home, and especially in some of the countries where missionary effort is put forth so vigorously, and, on the other, the intimate dependence of man's intellectual and spiritual development upon his physical condition, urges that we may hope for the best culture of the Christian graces in the hearts of men

only in proportion as adequate nourishment of their bodies is provided for.

I have been led to the conclusions that, in this country, many people, not only the well-to-do, but those in moderate circumstances also, use a needless quantity of food; that part of this excess, however, is simply thrown away, so that the injury to health, great as it may be, is doubtless much less than if all were eaten; that one great fault with our dietaries is an excess of meats and of sweetmeats; that even among those who desire to economize there is great pecuniary loss from the selection of materials in which the actual nutrients are really, though not apparently, dearer than need be; that many whose means are limited make still more serious mistakes in their choice of food, so that they are often inadequately nourished when they might be well fed at less cost; and, what seems the most painful thing of all, that it is generally the very poor who practice the worst economy in the purchase as well as in the use of their food.

The subject concerns the laboring classes in still other ways. Statistics as well as common observation bear emphatic testimony to the better condition of the American as compared with the European workman in respect to his supply of the necessities and comforts of life. Nowhere is this superiority more striking than in the quality and quantity of his food. And the difference in the dietaries of the two is especially marked in the larger amount of potential energy, of capability to yield muscular strength for work and to fulfill other uses in nutrition, which characterizes the food of the American. That the American workman, in many cases at least, turns out more work per day or per year than his European competitor is a familiar fact. That this superiority is due to more nutritious food as well as to greater intelligence is hardly to be questioned. But the better nourishment of the American wage-worker, as we shall see,

* See "The Food Question in America and Europe" by Edward Atkinson in this magazine for December, 1886.

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is largely due to our virgin soil. With the growth of population and the increasing closeness of home and international competition, his own diet cannot be kept up to its present nutritive standard, nor can that of his poorer neighbor and his foreign brother be brought up nearer to that standard, without better knowledge and application of the laws of food-economy.

Some time since, at the instance of the United States National Museum, and in behalf of its food collection, I was led to undertake a study of the chemistry of foods. This has included with other matter a series of analyses of some of our common food-materials. To give some of the more practical results of this work, especially as viewed in the light of late research upon the more general subject of nutrition, is the purpose of the present articles.*

A POUND of very lean beef and a quart of milk both contain about the same quantity of actually nutritious materials. But the pound of beef costs more than the quart of milk, and its nutrients are not only different in number and kind, but are, for ordinary use, more valuable than those of the milk. We have here an illustration of a principle, or rather of two principles, of fundamental importance in the economy of nutrition: our food-materials contain nutrients of different kinds and in different proportions, and the nutrients have different functions, different sorts of work to do in the support of our bodies. Add that it is essential for our health that our food shall supply the nutrients in the kinds and proportions our bodies require, and that it is likewise important for our purses that the nutrients be obtained at the minimum cost, and we have the fundamental tenets of our system of food-economy.

The greater part of our definite knowledge of these matters comes from chemical study of food-materials, and from experiments in which animals are supplied with food of various kinds and the effects noted. In these latter, the food, the *egesta*, solid and liquid, and, in many cases, the inhaled and exhaled air are measured, weighed, and analyzed. Hundreds, indeed thousands, of trials have been made with animals of many kinds, and a great number with human beings of both sexes and different ages. The best work has been done during the last two decades, nearly all of it in Europe, and the larger share in Germany. It involves the study of the profoundest problems of chemis-

try, physics, and physiology, the most elaborate apparatus, and the greatest care and patience of the workers. The labor of days and weeks is often required for a single experiment of a series, and the result of many series may often be condensed in a very few words. If one seeks famous names in this field he may find them in Liebig, Pettenkofer, and Voit in Germany; Payen and Claude Bernard in France; Moleschott in Italy; and Frankland, Playfair, Lawes, and Gilbert in England, and many others. If he questions the practical value of the results, let him see how they are being applied in the construction of dietaries for the common people in Germany, and what they indicate as to the errors of our food-economy at home. If he would see how results of recent research in one country may be ignored, because unknown, by the writers of a different language in another, let him examine some of our latest magazine articles and text-books, the names of the authors and publishers of which ought to be a guarantee for better things.

What we wish to consider now, however, is not the extent of the science, but some of its more important teachings in their applications to our daily life. Our task is to learn how our food builds up our bodies, repairs their wastes, yields heat and energy, and how we may select and use our food-materials to the best advantage of health and purse.

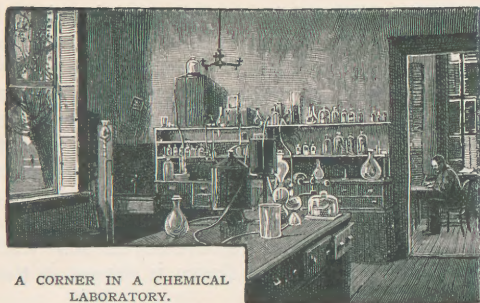
I begin our study together with a wholesome fear of the editor before my eyes, knowing well that back of the courteous hint to make these articles not too abstrusely scientific there was a repressed warning to avoid the tone and language of the college lecture-room as unsuited to the pages of a magazine. But I must crave a little latitude; the results of scientific research cannot be explained without some tedious technicalities and dry details.

HOW CHEMICAL ANALYSES ARE MADE.

If I cannot be interesting, I will be orthodox, and go back to the Catechism, whose second question is "Of what are you made?" and the answer, "The dust of the earth." The fact that underlies this answer, namely, the identity of the elements of our bodies with those of the material objects around us, is one of the many which chemistry explains. This fact, embodied in the solemn language of the primeval curse, "for dust thou art, and unto dust shalt thou return," impressed upon us

* I am indebted to Professor Baird, Secretary of the Smithsonian Institution and Director of the National Museum, for permission to reproduce here several charts prepared to illustrate the food collection; nor can I forbear adding that it was through the generosity

of Messrs. Thurber, Whyland and Co., of New York, in defraying a considerable portion of the pecuniary expense of the analyses hereafter referred to that the latter were made possible.



A CORNER IN A CHEMICAL LABORATORY.

with our earliest religious teachings, clothed in fantastic imagery by poets, and understood so vaguely in the science, and dwelt upon so mysteriously in the philosophy of the past, is divested of much of its mystery by the matter-of-fact investigation of the present. The chemistry of to-day tells us of what elements and compounds our bodies consist. It gives us at least a glimpse of the ways in which they are framed together by the wonderful processes of life, and how they go through the round of growth and fruition, and are by decay resolved again into the forms from which they came. And the research of the past few years has shown us that even this decay is a vital process carried out by living creatures, whose mission is to take off the effete matter and fit it for use again.

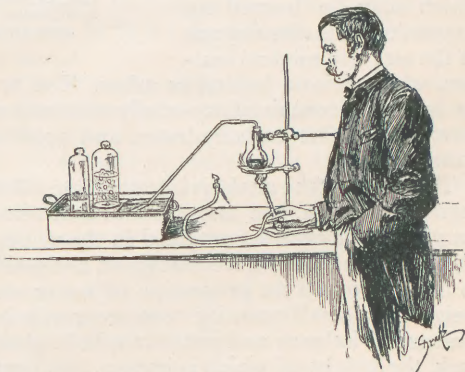
A friend of mine tells of an editor of a prominent journal—and a Boston editor at that—who was much surprised to learn that it is possible to tell by use of the balance, the combustion furnace, the filter, and other appliances of the chemical laboratory, just what elements and compounds and what proportions of each make up the air or a mineral, or how much nitrogen there is in muscle or protein in wheat flour. But to the chemist these are the most commonplace, though not always the simplest, things. Indeed, our everyday handling of food materials often involves processes, though crude ones, of analysis.

We let milk stand; the globules of fat rise in cream, still mingled, however, with water, protein, carbohydrates, and mineral salts. To separate the other ingredients from the fat, the cream is churned. The more perfect this separation, *i. e.*, the more accurate the analysis, the more wholesome will be the butter. Put a little rennet into the skimmed milk, and the casein, called in chemical language an albuminoid or protein compound, will be curdled and may be freed from the bulk of the water, sugar, and other ingredients by the cheese-press. To separate milk-sugar, a carbohydrate, from the whey is a simple matter. One may see it done by Swiss shepherds in their rude Alpine huts. But farmers find it more profitable to

put it in the pig-pen, the occupants of which are endowed with the happy faculty of transforming sugar, starch, and other carbohydrates of their food into the fat of pork.

The New England boy who on cold winter mornings goes to the barn to feed the cattle, and solaces himself by taking grain from the wheat bin and chewing it into what he calls "wheat-gum," makes, unknowingly, a rough sort of analysis of the wheat. With the crushing of the grain and the action of saliva in his mouth, the starch, sugar, and other carbohydrates are separated. Some of the fat, *i. e.*, oil, is also removed, and finds its way with the carbohydrates into the stomach. The tenacious gluten, which contains the albuminoids or protein and constitutes what he calls the gum, is left. When, in the natural order of events, the cows are cared for and the gum is swallowed, its albuminoids enter upon a round of transformation in the boy's body, in the course of which they are changed to other forms of protein, such as albumen of blood or myosin of muscle; or are converted into fat, or are consumed with the oil and sugar and starch to yield heat to keep his body warm and give him muscular strength for his work or play.

I am using such technical terms as protein and carbohydrates and speaking of chemical processes with which daily usage makes us chemists familiar and which the reader will find referred to so often in these articles that I wish him to become familiar with them also. Indeed, these things are so much a part of ourselves, so intimately connected with our every breath and motion and feeling, with our life and health and strength, that labor spent in learning about them cannot be lost. It will help toward understanding the facts if we note how some of them are found out. To this end I will introduce the reader into a laboratory, being aided in so doing by the illustrations of the chemical laboratory of Wesleyan Univer-



MAKING OXYGEN.

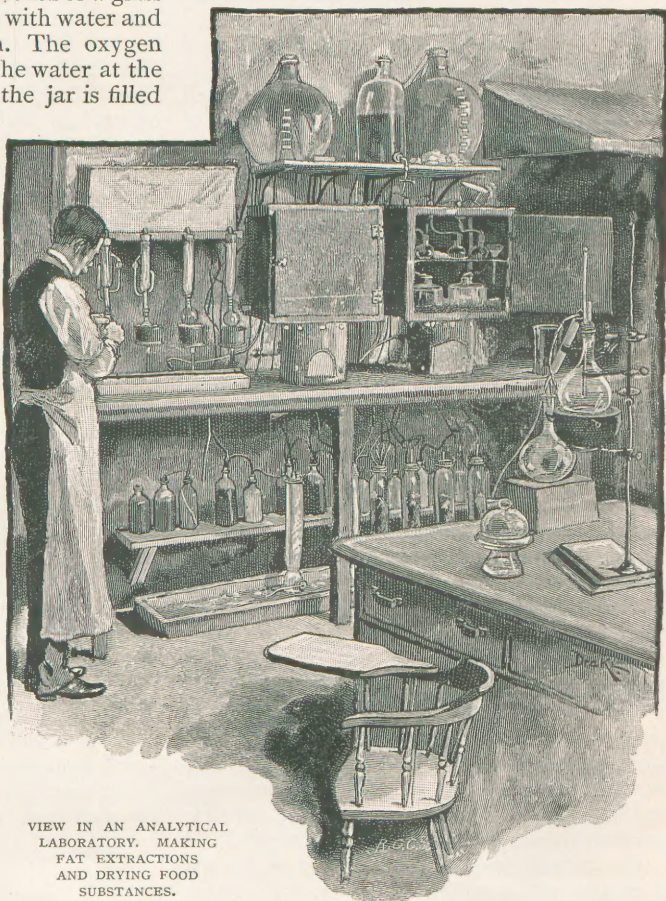
sity. They show the rooms in which some of the studies whose results are to be described beyond were made, and part of the apparatus actually employed.

At one of the desks a student may be seen preparing oxygen. In a little flask he places some chlorate of potash—the material which we use as a medicine for sore throat. This he heats by the flame of a peculiar lamp underneath the flask. The oxygen is given off as gas and passes through a glass tube which is bent downward so as to open under the mouth of a glass jar, which latter has been filled with water and inverted over water in a basin. The oxygen bubbles up into the jar, while the water at the same time runs out, and thus the jar is filled with the gas. It looks like ordinary air, but when the experimenter sets fire to a stick of wood, blows out the flame, thrusts the glowing end in the oxygen, it bursts instantly into a brilliant flame. A piece of phosphorus, kindled and placed in the oxygen, burns with a flame of blinding brightness. And a steel wire burns in this gas even more brilliantly than wood burns in ordinary air. Thus the student learns as he could not from textbook or lectures, that oxygen, which makes up nearly two-thirds of the weight of our bodies, and one-fifth of the weight of air, is the great supporter of combustion.

But our special purpose here is to note how chemical analyses are made. Let us take as an example a grain of wheat. It contains water, which we may dry out by heating; organic matter, which may be burned by combining with the oxygen of the air; and mineral matters, which remain behind as ashes. The organic matter contains fatty or oily substances, starch and other carbohydrates, and protein compounds.

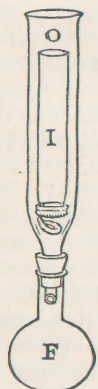
The object of the analysis is to separate these ingredients from one another and find what proportion of each is contained in the wheat. To make the analysis, we first grind the grain to flour. To find the proportion of water, we weigh off a small quantity very accurately in a chemical balance and put it in a little glass flask, the weight of which is known, and heat it for a number of hours, until the water is

driven out. When it is perfectly dry it is weighed again. The loss in weight represents the quantity of water in the flour. This heating is conducted in a drying oven which is kept hot by a gas flame inside the support on which the oven rests. In order to prevent the action of the oxygen of the air upon the flour while it is being dried, we keep a current of hydrogen gas continually passing through it. The apparatus for generating the hydrogen and forcing it through the flasks is shown in the



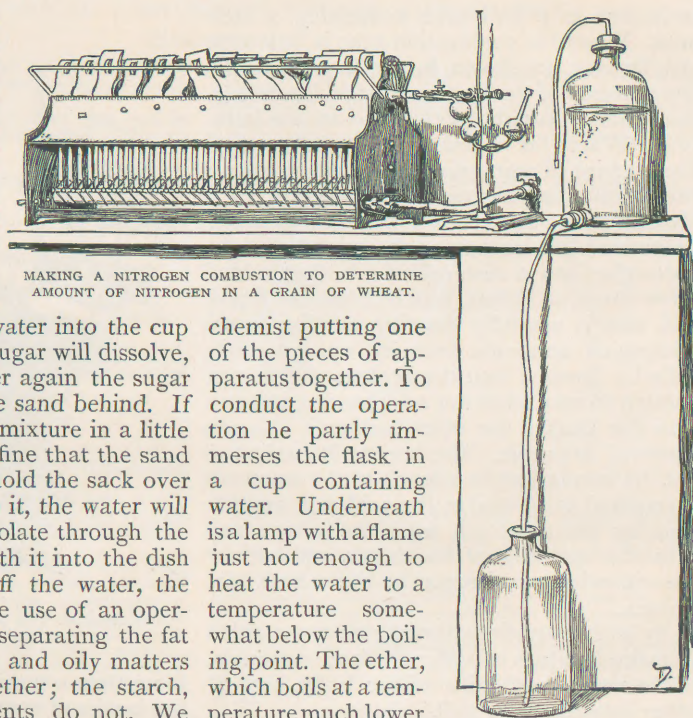
picture. In the large bottles above is sulphuric acid. This runs down the pipes into the tall narrow glass vessels on the floor. These latter contain zinc. When the acid comes in contact with the zinc, hydrogen gas is developed, and passes up by tubes through the top of the drying oven into the flasks. Such devices as these are necessary if we are to make large numbers of analyses with the greatest accuracy and speed. Like a steam-engine, they seem a little complicated, but the engineer understands his engine, and to the chemist his apparatus seems perfectly simple.

We have next to find out how much oily matter the wheat contains. For this purpose we must have some means of getting the oil out, and weighing it. The operation is by no means a difficult one. Suppose we have a mixture of sugar and sand and wish to find out how much sugar it contains. Sugar dissolves in water, sand does not. If we pour water into the cup containing the mixture, the sugar will dissolve, and if we pour off the water again the sugar will go with it and leave the sand behind. If instead of a cup we put the mixture in a little cloth sack, with meshes so fine that the sand will not pass through, and hold the sack over a dish and pour water into it, the water will dissolve the sugar and percolate through the cloth, carrying the sugar with it into the dish below. If then we boil off the water, the sugar will remain. We make use of an operation analogous to this in separating the fat from our wheat. The fatty and oily matters of the wheat dissolve in ether; the starch, gluten, and other ingredients do not. We therefore use ether in place of water for the solvent. Instead of the bag we place the flour in a little glass cylinder (I) having its lower end covered with filter paper. This small tube is put inside a larger one (O) whose lower end is drawn out into a neck like that of a funnel. This neck is then passed through the stopper of a little flask (F). If now we pour ether into the inner tube, it will dissolve the fat, percolate through the filter paper, and fall into the flask below. By passing successive portions of ether through the flour, we shall, after a time, dissolve out all the fat. But this would require a great deal of time and ether, both of which are expensive. Suppose we had some means by which



APPARATUS FOR
FAT EXTRACTION.

the ether, after bringing its freight of fat into the flask, could be driven out, leaving the fat behind, caused to return into the inner tube, dissolve another portion of fat and bring it into the flask, and be made to repeat the round again and again. Suppose, furthermore, this operation should be made to go on automatically, and that it could be carried on in several of these pieces of apparatus at once, while the analyst devoted himself to other work. Our analyses would thus be greatly facilitated. Precisely this is done in the apparatus at the left of the drying oven in the large picture, which shows the



MAKING A NITROGEN COMBUSTION TO DETERMINE
AMOUNT OF NITROGEN IN A GRAIN OF WHEAT.

chemist putting one of the pieces of apparatus together. To conduct the operation he partly immerses the flask in a cup containing water. Underneath is a lamp with a flame just hot enough to heat the water to a temperature somewhat below the boiling point. The ether, which boils at a temperature much lower than water, changes to vapor and passes upward between the inner and outer tubes into a long pipe which winds upward through the tank above like the worm of a still. The tank is kept filled with cold water; the ether vapor is condensed to liquid, falls back upon the flour in the inner tube, dissolves out another portion of fat, carries it into the flask below, and is then once more evaporated, leaving the fat in the flask; and so the same portion of ether keeps on its round, passing up in the form of vapor, coming back as liquid, and bringing fat with it into the flask. When the fat is all extracted the operator takes the apparatus apart, boils off the ether once more, and weighs the flask with the fat. Knowing how much the empty flask weighs, he has simply to subtract its weight from that of the flask with the fat in it; the difference is the weight of the fat.

The ways of finding the amount of nitrogen in food materials are of especial interest to us, because we use the nitrogen as a measure of the amount of protein, the most important of the nutritive ingredients. One of the most common of these ways, the "soda-lime method," as it is called in the laboratory, is illustrated in pictures herewith. The flour is heated with a mixture of soda and lime in a combustion-tube. The small diagram shows the tube ready for the heating or "combustion," as it is termed. Connected with the long combustion-tube which holds the flour and

soda-lime is a bulb-tube containing a little acid. When the combustion-tube is heated in the furnace, as shown in the larger picture, the nitrogen of the flour is changed to ammonia, which is caught in the acid in the bulb-tube. When this is done we have only to find the amount of ammonia and calculate from it the amount of nitrogen. The picture of a chemist sitting by the window shows this latter operation. He has poured the contents of the bulb-tube into a dish called a beaker, added a few drops of litmus, which colors the liquid red, and is carefully drawing another liquid containing ammonia from an upright tube, called a burette, into the beaker. When just enough to neutralize the acid has been drawn into the beaker the color suddenly changes from red to purple. The burette is marked so that he knows just how much of the ammonia is required to neutralize the acid not neutralized by the ammonia from the wheat, and thus the quantity of the latter, and with it the quantity of nitrogen in the wheat, are known.

By such operations as these we are enabled to make analyses of different food materials, of the tissues and fluids of the body, and of other substances as well.

THE CHEMICAL ELEMENTS AND COMPOUNDS OF THE BODY.

BEFORE entering upon our study of foods it will be well to consider with some detail the composition of the human body. For a brief statement of the elements nothing can serve us better than the accompanying reproduction of some of the case-labels of the food collection in the United States National Museum at Washington. The figures are as computed by Messrs. E. A. Welch and R. H. Pomeroy, students in this laboratory, who have been at more pains than any one else, so far as I am aware, to use data collated from all available sources. No one has ever made a complete chemical analysis of a human body, but anatomists have made numerous weighings of the different organs, and chemists have analyzed their constituents. From the figures thus obtained it is possible to make an approximate estimate of the composition of the body of an average man, as is here done.

The diagram on the opposite page will help to a clearer idea of the relative proportions of the elements in the body. In the latter the proportions are expressed in percentages, while in the National Museum labels the estimated weights are stated in pounds.

These thirteen elements are combined with one another in the body, forming a great variety of compounds. Chemists have discovered



DETERMINING THE AMOUNT OF AMMONIA WHICH CAME FROM THE NITROGEN OF THE WHEAT.

more than a hundred different compounds in the bodies of man and other animals. Instead of attempting to enumerate all of them here, it will be more to our purpose to consider some of the principal ones. In doing so we may take advantage of the fact that the compounds in the body and those in the food are very similar, and discuss them together.

An ox eats grass and meal and transforms the compounds they contain into meat. We eat meat and wheat and change them into the materials of our bodies. Some of the compounds in the food are destroyed, others are only slightly changed in these transformations.

Water, which consists of the two elements hydrogen and oxygen, is a most important constituent of all animal and vegetable tissues. It makes up about seven-eighths of the whole weight of milk and of the flesh of oysters, one-fourth that of potatoes and very lean meat (muscle), one-third of bread, a little over half of well-fattened beef or mutton, and one-eighth of the weight of flour and meal. The body of an average man would, by the above calculation, contain about sixty-one per cent. or three-fifths water.

Of the materials of our bodies and of our foods the larger part is combustible, as was the case with the grain of wheat; that is to say, it will be burned if put in the fire. A small residue will, however, remain as ashes. This incombustible portion includes the so-called mineral matters. These latter consist of the metals potassium, sodium, magnesium, calcium, and iron, combined with other elements, as oxygen,

CHART I.—CHEMICAL COMPOSITION OF THE HUMAN BODY.

ELEMENTS.

The chemical compounds of which our bodies are made up are shown by chemical analysis to consist, mainly, of thirteen elements.

Five of these elements are, when uncombined (*i. e.*, each by itself and not united to any other element), gases. They are named:

1. Oxygen, 2. Hydrogen, 3. Nitrogen, 4. Chlorine, 5. Fluorine.

The other eight are solid substances. Of these, three are non-metals:

6. Carbon, 7. Phosphorus, 8. Sulphur.

The remaining five are metals:

9. Iron, 10. Calcium, 11. Magnesium, 12. Potassium, 13. Sodium.

Besides the above thirteen elements, minute quantities of a few others, as silicon, manganese, and copper, are found in the body.

CARBON—A SOLID.

The body of a man weighing 148 pounds would contain about 31 pounds of carbon.

The diamond is nearly pure carbon. Graphite (the so-called "black lead" of lead-pencils), anthracite coal, coke, lamp-black, and charcoal are impure forms of carbon.

Carbon exists in combination with other elements in the body, of which it makes about one-fifth the whole weight, and in food.

Carbon burns, *i. e.*, combines with oxygen. In this combustion, heat and force are generated and carbonic acid gas formed. The carbon taken into the body in food combines with the oxygen of the inhaled air, yielding heat to keep the body warm and force, muscular strength, for work. The carbonic acid is given out by the lungs and skin. Carbon thus serves as fuel for the body and is the most important fuel element.

PHOSPHORUS—A SOLID.

About 1 pound and 6 ounces of phosphorus would be found in the body of a man weighing 148 pounds.

Phosphorus is a non-metal, light, very inflammable, and so soft that it is easily cut with a knife. Since it burns so readily in air, it is here kept under water.

United with oxygen, phosphorus forms what is known as phosphoric acid. This, with lime, makes phosphate of lime. Most of the phosphorus of the body occurs in this form in the bones and teeth, though it is also found in the flesh and blood, and especially in the brain and nerves.

LABELS FROM CASE OF SPECIMENS, ILLUSTRATING COMPOSITION

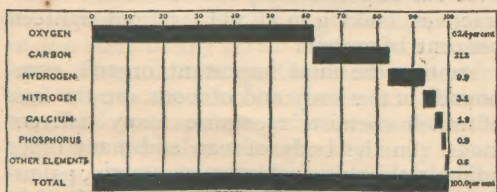


DIAGRAM I.

ESTIMATED PROPORTIONS OF CHEMICAL ELEMENTS.

phosphorus, sulphur, and chlorine. Thus, in bone we have phosphate of lime or calcium phosphate, which consists of calcium, phosphorus, and oxygen; in muscle, potassium phosphate and potassium chloride, the latter a compound of potassium and chlorine, and so on. The mineral matters make about thirty per cent. of the weight of bone, one per cent. of the flesh and blood of animals, and from one-half of one to two per cent. of our ordinary vegetable food materials. The mineral matters constitute about six per cent. of the whole weight of the body of an average man.

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The composition of the bodies of different persons varies greatly with age, size, fatness, etc. The amounts of the several elements in the body of an average healthy man, five feet eight inches high, weighing 156 pounds with, and 148 pounds without, clothing, may be roughly estimated to be, in pounds and hundredths of a pound, somewhat as follows:

WEIGHTS OF CHEMICAL ELEMENTS IN THE BODY OF A MAN WEIGHING 148 POUNDS.

| | | |
|------------|------|--------|
| Oxygen | 65.4 | pounds |
| Carbon | 31.3 | " |
| Hydrogen | 14.6 | " |
| Nitrogen | 4.6 | " |
| Calcium | 2.8 | " |
| Phosphorus | 1.4 | " |
| Potassium | .34 | " |
| Sulphur | .24 | " |
| Chlorine | .12 | " |
| Sodium | .12 | " |
| Magnesium | .04 | " |
| Iron | .02 | " |
| Fluorine | .02 | " |

Total 148.00 pounds

HYDROGEN—A GAS.

The body of a man weighing 148 pounds is estimated to contain about 14½ pounds of hydrogen, which, if set free, would fill about 2600 cubic feet.

Hydrogen, when uncombined, is a gas. It is the lightest substance known. Combined with oxygen it forms water, of which it constitutes one-ninth of the whole weight. Hydrogen occurs in combination with other elements in the body and in food.

Hydrogen, like carbon, unites with oxygen of the inhaled air in the body, thus serving as fuel. The water produced is given off in the respiration through the lungs, and as perspiration through the skin.

CALCIUM—A METAL.

The body of an average man weighing 148 pounds has been estimated to contain some 3 pounds of calcium.

Calcium is a metal somewhat similar in appearance to magnesium or zinc. It is very difficult to obtain free from other elements. United with oxygen it forms lime. This, with phosphoric acid, makes phosphate of lime, the basis of the bones and teeth, in which nearly all the calcium of the body is found. With carbonic acid, it forms carbonate of lime, the chief ingredient of marble and limestone.

OF HUMAN BODY, IN FOOD COLLECTION OF NATIONAL MUSEUM.

The combustible portion of the body and of the food that nourishes it consists of so-called organic compounds. Since these are the most important substances we shall have to do with in our study of foods and nutrition, we ought to have a tolerably clear understanding of the nature of at least the principal ones.

If from a piece of meat we remove the bone, gristle, and fat as completely as practicable, and subject the remaining "lean" (muscle) to chemical analysis, we shall find about one-fourth, or, to speak more accurately, from twenty-two to thirty per cent., of it to consist of organic compounds, the rest being water with a very little mineral matter. Even if all the visible fat is removed, part of this organic matter will consist of fat in microscopic particles. The fatter the animal from which the meat comes, the more of these minute particles of fat and the less water will there be in the muscle, a fact, by the way, which has the most interesting bearing upon the composition of our own bodies, as we shall see later

on. If, however, we assume that the fat and the mineral matter are both out of the way, some very remarkable compounds will remain. The bulk will consist of substances very similar to the albumen or "white" of eggs, and hence called albuminoid—albumen-like—compounds. They are sometimes called proteids, but the name albuminoids is perhaps preferable. Albuminoids in different forms make the basis of blood and muscle. Fresh blood contains blood-albumen and other albuminoids; coagulated blood contains fibrine. Muscle contains muscle-albumen, and other albuminoids called syntonin and myosin. The last is the chief constituent, except water, of muscle. Many persons are surprised to learn that myosin, instead of being the tenacious substance of which muscle is commonly supposed to consist, is in living muscle probably liquid or semi-liquid. How the contractile power of the muscle of an athlete can be exerted by liquid or semi-liquid matter is one of the unsolved problems of chemical physiology.

Albuminoids occur in great variety in plants as well as in animals, but they all consist of the four elements carbon, oxygen, hydrogen, and nitrogen, with perhaps a little sulphur or phosphorus.

Along with muscle, the meat contains what we call gristle, the substance that bothers us so much when we try to carve with a dull knife. This name, however, is applied to several substances, as tendon and cartilage, which, with skin and bone, etc., are called connective tissues. These tissues consist mainly of compounds like the collagen of tendon and the ossein of bone. They are very similar to gelatin (glue) and are changed to gelatin on heating with water. They are hence termed gelatinoids. The gelatinoids are thus the principal ingredients of connective tissue, as albuminoids are the principal ingredients of muscle and blood. The gelatinoids consist of the same elements as the albuminoids; these two classes differ from the other organic compounds in that they contain nitrogen, which most of the others do not.

In speaking of the ingredients of foods, it is customary to give to both albuminoids and gelatinoids the generic name of protein. Protein compounds are the most important of all the ingredients of foods.

There is still another class of nitrogenous substances in meat which, though so small in quantity as to be often left out of account, are nevertheless extremely interesting. These are known in the chemical laboratory as creatin, creatinin, carnin, etc., and are designated collectively as "extractives," because they are extracted from flesh by water, as in the case with beef tea and Liebig's Meat Extract.

Chemists find certain analogies between these extractives from flesh and thein and caffen, the active principles of tea and coffee, which they likewise resemble in their stimulating effect. The African traveler Rohlfs tells how invigorating he found a little meat extract spread on a piece of dry bread. The familiar fact that dogs that are quiet and subdued with vegetable food grow fierce on meat is most probably explained as the effect of these same substances. Some people, oftenest those of a fine nervous organization, I presume, find in meat a stimulating effect approaching that of wine. The extractives are similar to alcohol in that they do not form tissue, flesh, or fat. They have, apparently, no effect as fuel. In brief, they are stimulants rather than nutrients.

The extractives give the taste to fresh meat. They impart their savory smell and taste to soups, give roast beef its appetizing odor, and steak its toothsome taste. Our craving for meat is largely due to our fondness for these extractives, as the tastelessness of meat from which they have been removed in making soups bears witness. Indeed, I mistrust that the excessive use of meat, from which the average gourmand—and many of us are veritable gourmands in this respect—suffers so much harm to health, is traceable to the redolence and relish of creatin and other extractives. Though the extractives are different from true protein compounds, they contain nitrogen, and we may follow a common usage and class them as protein.

The body of an average man will contain about eleven per cent. of albuminoids, a little over six of gelatinoids, and about one of extractives, making in all not far from eighteen per cent. of protein.

Among the most important organic compounds of the body and of foods are the fats, of which chemists recognize many different kinds. In the body of man and many other animals, the principal ones are stearin, palmitin, and olein. Stearin, which is obtained in large quantities from beef tallow, is much used for candles, because it does not melt readily. Olein, on the other hand, is an oil at ordinary temperature, and is a chief ingredient of olive oil. A large part of the fat of the human body consists of olein. The fats just named consist of the three elements carbon, oxygen, and hydrogen.

The brain, nerves, and spinal cord contain substances called protagon, lecithin, cerebrin, etc., which, though commonly classed as fats, contain nitrogen and phosphorus, and are therefore known as nitrogenized and phosphorized fats. They have an especial interest because they are believed to be somehow connected with mental activity.

The fats make up about sixteen per cent. of the weight of an average man.

The other compounds in the body are so small in amount that we might pass them by. One class, however, the carbohydrates, demand a moment's notice, because they make up a large part of our food. These include sugar, starch, dextrin, and like substances. The principal ones in the body are glycogen, or liver-sugar, and inosite, or muscle-sugar. They consist of carbon, oxygen, and hydrogen, the same elements as occur in the fats, though not in the same proportions. They constitute only a fraction of one per cent. of the weight of a healthy human body.

To recapitulate, the estimated weights of these compounds in the body of an average man weighing 148 pounds, or, with clothing, 156 pounds, may be stated as in the figures below. The percentage composition is set forth more graphically in Diagram II.

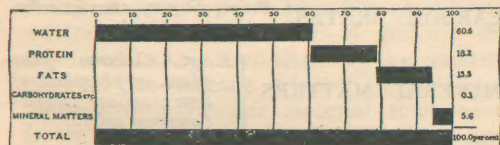


DIAGRAM II.—ESTIMATED PROPORTION OF CHEMICAL COMPOUNDS IN THE HUMAN BODY.

Compounds in the Body of a Man weighing 148 Pounds.

| | |
|-----------------------|-------------|
| Water | 90.0 pounds |
| Protein | 26.6 " |
| Fats | 23.0 " |
| Carbohydrates | 0.1 " |
| Mineral matters | 8.3 " |

Total 148.0 pounds.

Of course I do not mean that this is an exact statement of the amounts of the compounds in the body of any given man or of an ideal man. These figures, like those above cited for the elements, are simply an attempt to show in a general way in about what proportions the materials probably occur in the body of an ordinary man of average size and weight. The bodies of different people vary widely in composition. The flesh of lean persons has more water, and that of fat persons more fat, in proportion to the whole weight. A lean man may gain in weight without corresponding gain of muscle or other protein compounds. The store of fat in his body increases. Part of this fat accumulates in adipose tissue next to the skin and in other masses such as we see in meats. Part is disseminated in small particles through the muscles, bones, and other tissues.

In studying the tissues of animals we find a considerable proportion of these particles of

* This statement is based not only upon observations recorded in memoirs and text-books of physiological chemistry, but also upon a somewhat extended series

fat to be so small as to be visible only by aid of a powerful microscope. A piece of muscle in which no fat can be seen with the naked eye may yield a considerable quantity of fat when treated with ether in the apparatus for fat-extraction. The muscles, bones, and other tissues contain large proportions of water. As the fat accumulates in them, part of the water goes out to make way for it. When, on the other hand, fat is removed from the living tissues, more or less of the water is restored.*

Accordingly a gain of weight of the body may mean a gain, not only of a corresponding weight of fat, but of enough more fat to make up for the water that is lost. To "get stout" is really to grow fat faster than the scales tell us, and to grow lean is to grow watery.

Of course gain of weight of the body may be due to increase of other materials than fat, as in the case of growing animals. So, too, there may be increase of protein with loss of fat, as in the muscle of an athlete when in a course of training.

PROPORTIONS OF NUTRITIVE INGREDIENTS IN FOOD MATERIALS.

HAVING learned what our bodies consist of, we have next to study the composition of the food by which they are nourished. Viewed from the standpoint of their uses in the nutrition of man, our food materials may be regarded as consisting of edible material and refuse, and the edible material as made up of water and nutrients. The accompanying adaptation of charts prepared for the food collection of the National Museum summarize what is most necessary to say here about the constituents of food.

We have next to notice the amounts of these ingredients in different food materials. The details will perhaps be best explained by an example.

CONSTITUENTS OF SPECIMEN OF SIRLOIN OF BEEF.

| | <i>In flesh, edible portion.</i> | <i>In meat as bought, including refuse.</i> |
|--------------------------|----------------------------------|---|
| | <i>Per cent.</i> | <i>Per cent.</i> |
| Refuse, bones, etc. | None. | 25 |
| Water | 60 | 45 |
| Protein | 20 | 15 |
| Fat | 19 | 14 1/4 |
| Mineral matters | 1 | 0 3/4 |
| Total | 100 | 100 |

As stated above, some fat sirloin of beef was found to consist of about one-fourth refuse

made in this laboratory but still awaiting publication. It rests upon the assumption that the changes in composition of the tissues of the human body are similar

CHART II.—INGREDIENTS OF FOOD MATERIALS.

NUTRIENTS AND NON-NUTRIENTS.

CLASSES OF NUTRIENTS.

Our ordinary food materials, such as meat, fish, eggs, potatoes, and wheat, etc., consist of:

REFUSE—as the bones of meat and fish, shells of eggs, skin of potatoes, and bran of wheat.

EDIBLE PORTION—as the flesh of meat and fish, white and yolk of eggs, wheat flour.

The edible substance consists of:

WATER,
NUTRITIVE INGREDIENTS OR NUTRIENTS.

The principal kinds of nutrients are:

- 1. PROTEIN,
- 2. FATS,
- 3. CARBOHYDRATES,
- 4. MINERAL MATTERS.

The water, refuse, and salt of salted meat and fish are called non-nutrients, because they have little or no nutritive value. The water contained in foods and beverages has the same composition and properties as other water; it is, of course, indispensable for nourishment, but is not a nutrient in the sense in which it is here used. In comparing the values of different food materials for nourishment, we may leave the refuse and water out of account and consider only the nutrients.

The following are familiar examples of compounds of each of the four principal classes of Nutrients:

- PROTEIN
- a ALBUMINOIDS: *E. g., Albumen (white) of eggs; casein (curd) of milk; myosin, the basis of muscle (lean meat); gluten of wheat, etc.*

b GELATINOIDS: *E. g., Collagen of tendons; ossein of bones, which yield gelatin or glue.*

Meats and fish contain very small quantities of another class of compounds called "extractives" (the chief ingredients of beef tea and meat extracts), which contain nitrogen, and hence are commonly classed with protein.

- FATS
- E. g., Fat of meat; fat (butter) of milk; olive oil; oil of corn, wheat, etc.*

- CARBOHYDRATES
- E. g., Sugar, starch, cellulose (woody fiber).*

- MINERAL MATTERS
- E. g., Calcium phosphate, or phosphate of lime; sodium chloride (common salt).*

It is to be especially noted that the protein compounds contain nitrogen, while the fats and carbohydrates have none. The average composition of these compounds is about as follows:

| | Protein. | Fats. | Carbohydrates. |
|---------------|--------------|----------------|----------------|
| Carbon | 53 per cent. | 76.5 per cent. | 44 per cent. |
| Hydrogen ... | 7 " | 12.0 " | 6 " |
| Oxygen | 24 " | 11.5 " | 50 " |
| Nitrogen | 16 " | None | None |
| | 100 " | 100.0 " | 100 " |

bone, etc., and three-fourths edible flesh. The edible portion was analyzed and found to contain, approximately, sixty per cent. of water and forty per cent. of nutrients. Of the nutrients the protein constituted, in round numbers, twenty, the fats nineteen, and the mineral matters one per cent.

Such numerical statements, however, are not entirely satisfactory, especially when a number are to be studied at once. Diagram III. (pages 70 and 71), in which the proportions of the ingredients are indicated by shaded bands, will doubtless be more acceptable.

Until within the past dozen years very little attention has been given in this country to the chemistry of animal and vegetable products, and most of the work actually done has had reference to their agricultural values. With the exception of analyses of cereals and dairy products we have very few American

studies of materials used as food for man, aside from those referred to above as executed in behalf of the National Museum, and a series of investigations of the chemistry of food-fishes made for the United States Fish Commission. Much more work in this direction, including the more purely scientific study of the constitution of the materials, is, therefore, most pressingly needed. At the same time the analyses at hand, which have been used in compiling the figures of the diagram, will suffice to give a general and, I think, tolerably correct idea of the average composition of the materials. In some cases where American analyses are lacking, particularly of vegetable foods, I have used European analyses, of which a large number are on record.

I ought to say that different specimens of the same kind of food material may vary

to those found to take place in the bodies of other animals. It is by no means urged that the quantities of water and fat which thus mutually replace each other are exactly the same. A striking illustration of

the mutual replacement of water and fat may be seen in the case of the lean and the fat mackerel in Part II. of the double-page diagram of composition of food materials beyond.

widely in composition and that the analyses here given represent averages. Examples of these variations are shown in the cases of oysters and of mackerel in Part II. of the table. In these, however, the differences are unusually wide, although very considerable variations are found in other materials, especially in meats.

The diagram tells its story plainly, and I need now call attention to but few points. It is interesting to note, in Part I., the differences in the amounts of refuse and edible portion in the different kinds of meats, fish, etc., as they are ordinarily found in the markets. Thus in some of the specimens of beef, as the round steak, the bone and other inedible materials amount to only ten per cent. of the whole, whereas in the flounder the refuse amounts to two-thirds, and the edible portion to only one-third, of the whole. The bone, though counted here as refuse, yields, when properly boiled, a considerable quantity of nutritive matter, chiefly in the form of gelatine and fats. Fish, as we buy them in the markets, have on the average a larger proportion of refuse and less edible material than meats. Dairy products and most vegetable foods have very little refuse.

In examining the edible portion of the materials, as shown in Part II., it is interesting to note the wide variations in the proportions of water and of nutritive substances. In general the animal foods contain the most water and the vegetable foods the most nutrients, though potatoes and turnips are exceptions, the former being three-fourths and the latter nine-tenths water. Butter, on the other hand, though one of the animal foods, has on the average about nine per cent. of water. The milk from which it is made is not far from seven-eighths water. As stated above, meats have more water in proportion as they have less fats, and *vice versa*, the fatter the meat the less amount of water in it. Thus, very lean beef (the muscle of a lean animal from which the fat has been trimmed off) may have seventy-eight per cent. of water and only twenty-two per cent. of nutrients. The rather fat sirloin of the diagram has sixty, and the very fat pork only about ten per cent. of water. The flesh of fish is in general more watery than ordinary meats, that of salmon being five-eighths water; codfish, over four-fifths; and flounder, over six-sevenths. Flour and meal have but little water, and sugar almost none.

In examining the proportions of individual nutrients, protein, fats, and carbohydrates, the most striking fact is the difference between the meats and fish, on the one hand, and the vegetable foods on the other. The vegetable foods are rich in carbohydrates, starch, sugar,

etc., while the meats have not enough to be worth mentioning. On the other hand the meats abound in protein and fats, of which the vegetable foods usually have but little. Beans and oatmeal, however, are rich in protein, while fat pork has very little.

The comparative composition of oysters and milk is worth noting. Both contain about the same total amounts of nutrients, but the proportions are quite different, the oysters having the more protein, and the milk the more fat. Roughly speaking, we may say that there is not a very great deal of difference between the nutritive values of a quart of oysters and a quart of milk. Considering the cost, however, the oysters are far the more expensive food.

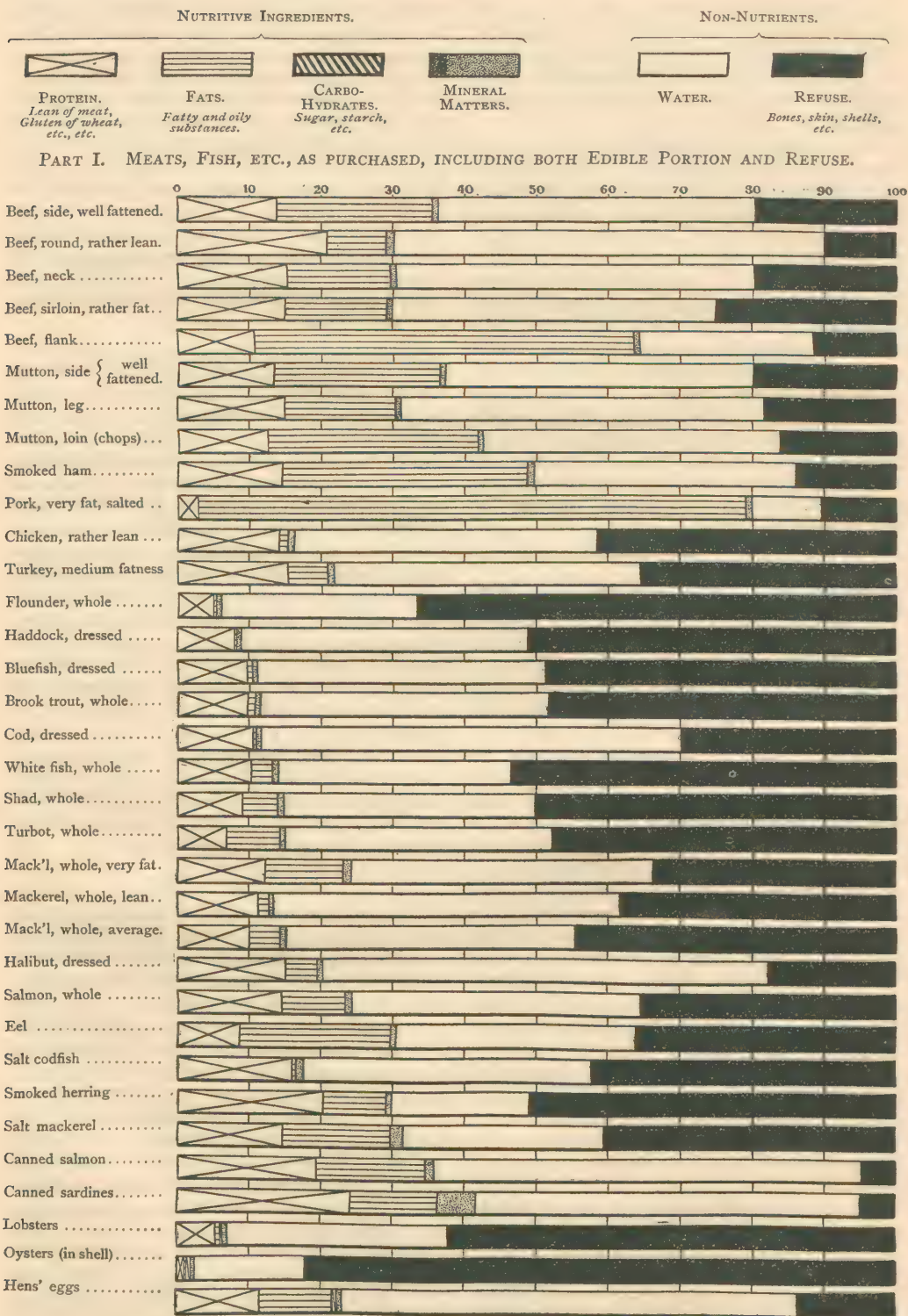
I have noticed that people in looking over such tables as this sometimes get at first a wrong impression. Thus rice contains about seven-eighths, and potatoes only one-fourth nutritive material. The first inference is that the rice is much more nutritious than potatoes. In one sense this is true; that is to say, a pound of rice contains more than twice as much nutrients as a pound of potatoes. But if we take enough of the potatoes to furnish as much nutritive material as the pound of rice, the composition and the nutritive values of the two will be just about the same. In cooking the rice we mix water with it, and may thus make a material not very different in composition from potatoes. By drying the potatoes they could be made very similar in composition and food value to rice. Taken as we find them, a pound of rice and three and a half pounds of potatoes would contain nearly equal weights of each class of nutrients and would have about the same nutritive value.

FLOUR AND BREAD.

THE composition of wheat flour and wheat bread are worth notice here. The chief difference is in the water, which makes about one-ninth the weight of the flour and one-third that of the bread. Of course different kinds of flour and bread vary widely in composition. The composition of wheat flour here stated is the average of a large number of analyses of American specimens, and doubtless represents very closely the average composition of the flour which people ordinarily buy. The figures for bread are the average of four analyses of loaves purchased at different times at bakeries in Middletown, Connecticut. They agreed very closely in composition with each other and with an excellent specimen of home-made bread. I infer, therefore, that this was better than the average baker's bread, a supposition confirmed by published analyses of the latter,

DIAGRAM III. NUTRITIVE INGREDIENTS, WATER, AND

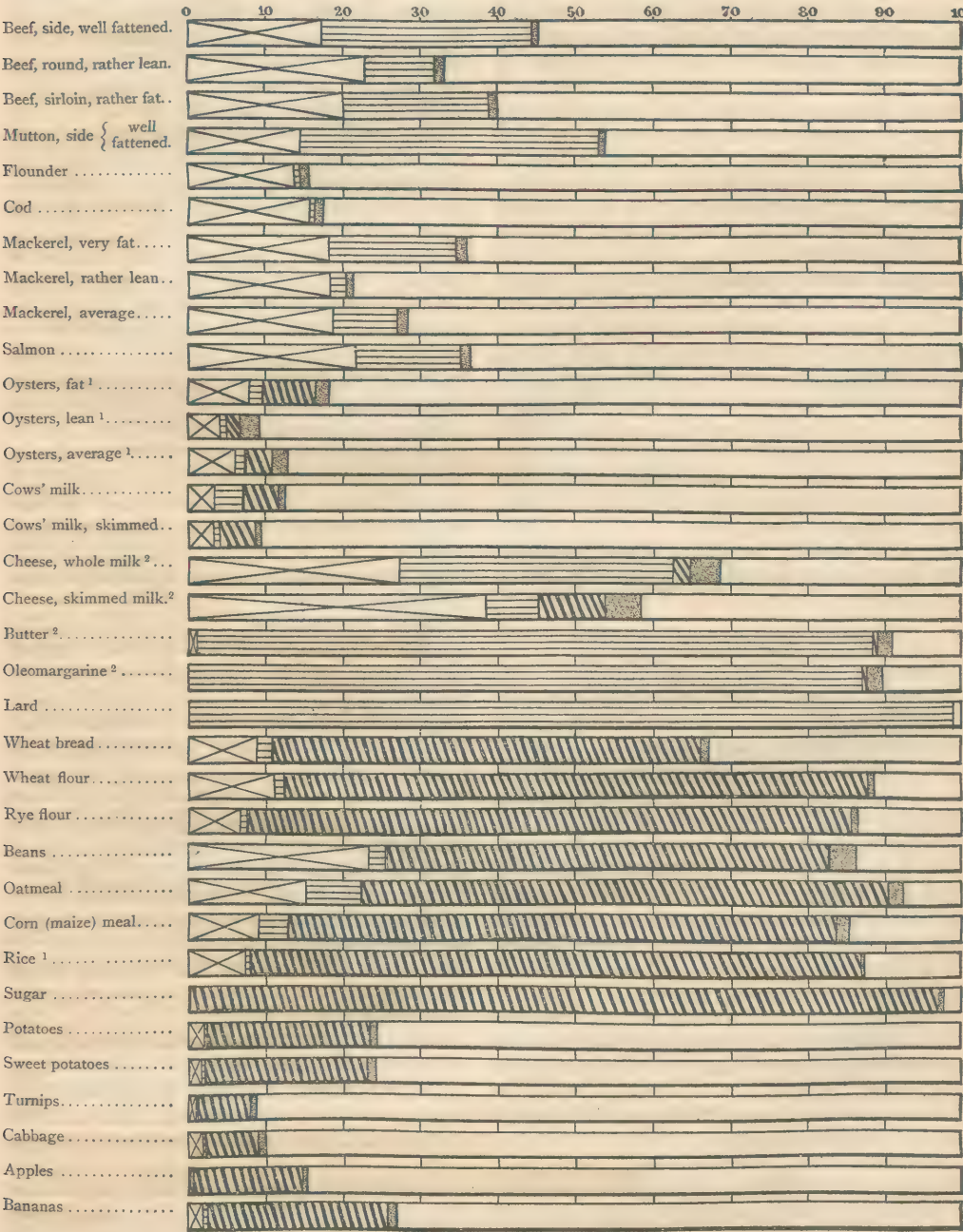
PERCENTAGES OF THE DIFFERENT CONSTITUENTS



INDICATED BY SHADED DEVICES.

EXPLANATIONS.—Of the different classes of nutritive ingredients or nutrients of food the protein compounds (“muscle-formers”) are the most important in the sense that they alone form the basis of the blood, muscles, tendons, and other nitrogenous tissues of the body. Protein, fats, and carbohydrates of food are all transformed into the fat of the body and all serve as fuel to yield heat and energy (strength) for muscular work. As fuel, one part by weight of fats is estimated to be equivalent to over two parts of protein or carbohydrates. A proper diet will include all the nutrients in proportions fitted to the needs of the user.

PART II. MEATS, FISH, ETC., EDIBLE PORTION; DAIRY PRODUCTS; VEGETABLE FOODS.



¹ In respect to quantity of nutrients.

² Mineral matters include salt.

which often show a much larger percentage of water, sometimes forty per cent. or more. In using the word "better" I do not refer to flavor, color, or texture, but to the proportion of nutrients and water. In making bread, a very little butter or lard and yeast and a good deal of water, by itself or in milk, are added to the flour. In the fermentation of the dough in rising, minor transformations take place in the carbohydrates, the chief being the change of sugar to carbonic acid gas and alcohol. In the baking, the alcohol and gases are mostly driven off, and part of the water goes with it. The chief difference between the flour and bread, therefore, is that the bread is more bulky, the gases having expanded it, and that it contains more water. In other words, in making flour into bread the baker renders it more palatable and increases the bulk and weight, but adds very little nutritive material. For him to manipulate it so as to get the most bulk and weight from the least flour is perfectly natural, and his loaf is apt to contain a large percentage of water and have considerable space inside filled with air and gas. The price of the bread per pound is apt to be twice that of the flour. When the poor man buys his pound loaf of bread of the baker for seven or eight cents he thus gets no more nutritive material than the well-to-do man obtains for three cents in the flour which he has baked at home. But if the poor man's family have no conveniences for making the bread, there is nothing left for them to do but buy it from the baker.

BUTTER AND OLEOMARGARINE.

WITHIN a few years past substitutes for butter have become a very important article of commerce. The most important of these, oleomargarine, agrees very closely in chemical composition with butter from cows' milk, the chief difference being that the oleomargarine contains smaller proportions of the peculiar fats, butyric, etc., which give butter its agreeable flavor. It is made by taking beef fat or lard, extracting part of the stearin, a material which is familiarly known in candles, and adding a small amount of butter to the residue. It is this small quantity of butter which gives the butter-flavor to the whole.

As will be explained when we come to consider the digestibility of foods, the difference in digestibility between butter and oleomargarine is at most too small to be of any considerable consequence for ordinary use. The nutritive values of the two are very nearly the same. In fulfilling one of the most important functions of food, that of supplying heat and muscular energy, butter and oleomargarine excel in efficiency all, or nearly all, of our other

common food materials; at least such is the outcome of the best experimental testimony. In appearance and flavor the common kinds of oleomargarine resemble butter so closely that it is difficult even for an expert to distinguish between them.

These butter substitutes are manufactured at very low cost, so that they can be sold at retail at about half the price of butter. They are, therefore, food products of large economic importance and of great benefit to that large class of our population whose limited incomes make good dairy butter a luxury, and, for that matter, to all who need to economize in their living expenses.

Like many other manufactured food products, oleomargarine is liable to be rendered unwholesome by improper materials and methods of manufacture. Butter, likewise, is often improperly made and is liable to become unwholesome. In the considerable mass of evidence which has come under my own observation there is no indication that butter substitutes, as they are actually sold in our markets, average less wholesome or healthful or are in any way less fit for human food than ordinary butter, though some observers in whose judgment I have confidence are inclined to think that on the whole the advantage as regards wholesomeness is somewhat in favor of butter. Among the chemists who are recognized as authorities in these matters, both in this country and in Europe, there is very little difference of opinion as to the value of oleomargarine for food.

There is, however, a popular prejudice against imitation butter which is very unfortunate, especially for people in moderate circumstances and for the poor, whom it is most calculated to benefit. This prejudice, which a new food material very naturally meets, is fostered, and often conscientiously, by representatives of the dairy interest, which fears from imitation butter a damaging competition, though the most accurate statistics show it to be far less serious than is generally believed. On the other hand, the benefit which butter substitutes are calculated to bring is largely prevented, and an immense wrong is done by the very general sale of the imitation under the guise and name and at the price of butter.

In a number of States in which the dairy interests are large, the manufacture and sale of butter substitutes has been prohibited by legislative action. In other States laws have been enacted to regulate their sale and prevent fraud. An attempt was made in Congress to check the manufacture and sale by taxation sufficient to bring their cost nearly up to that of butter. In the law as actually passed, however, the tax was very much reduced, so that

while it may help toward preventing improper sale of butter substitutes and, by obliging sellers to pay high license fees, may considerably interfere with their general use, it will not be as effective in excluding them from the markets as was desired.

This is a case where mechanical invention aided by science is enabled to furnish a cheap, wholesome, and nutritious food for the people. Legislation to provide for official inspection of this, as of other food products, and to insure that it shall be sold for what it is and not for what it is not, is very desirable. Every reasonable measure to prevent fraud, here as elsewhere, ought to be welcomed. But the attempt to curtail or suppress the production of a cheap and useful food material by law, lest the profits which a class, the producers of butter, have enjoyed from the manufacture of a costlier article may be diminished, is opposed to the interests of a large body of people, to the spirit of our institutions, and to the plainest dictates of justice.*

IN discussing the composition of our foods we must consider not only the quantities of nutritive ingredients which they contain, but also the part each one of these classes of nutrients has to perform in the nourishment of the body, and the proportions which are appropriate for the diet of different persons.

The protein compounds, sometimes called "muscle-formers," are the only ones which contain nitrogen. According to the best experimental evidence they alone form the basis of blood, muscle, tendon, and other nitrogenous tissues of the body. As these tissues are worn out by constant use they are repaired by the protein of the food. The protein, fats, and carbohydrates are all transformed into fat. They all seem to share, therefore, in the formation of the fat of the body. They all likewise serve as fuel to maintain the heat of the body and to yield muscular energy for its work. Late experiments indicate that in those serving as fuel, one part by weight of fats is equivalent to a little over two parts of either protein or of carbohydrates. The mineral matters make up a large part of the bones and teeth, small proportions are contained in the other tissues, and they are necessary for nutrition in various other ways.

It is a fundamental principle of food economy that the diet should contain nutritive material adapted to the wants of the consumer.

A great deal of experimenting and observation have been devoted to the determination of the quantities of protein, fats, and carbohydrates needed for the daily nourishment of individuals of different age and sex, at work or at rest, and subject to the varied conditions of life. In Germany, where the subject has been most thoroughly studied, it has come to be commonly accepted that about 4.2 ounces of protein, 2 ounces of fats, and 17.6 ounces of carbohydrates will make a fair daily ration for a laboring man of average weight and doing moderate work. Of course he can get on with less of one if he has more of the others. But there is a minimum below which he cannot go without injury, and his amount of protein should not fall much below the 4.2 ounces per day, though protein, as we shall see later on, is by far the costliest of the nutrients. In animal foods, furthermore, it is usually associated with the so-called extractives, which have a peculiarly agreeable flavor. In accordance with one of those universal processes of natural selection which science is gradually helping us to understand, the food of the poor is apt to contain too little protein and that of the rich too much.

The flesh of codfish contains, aside from water, little else than protein, butter is almost wholly fat, and sugar and starch are carbohydrates. The lean meats are similar to codfish; fat pork resembles butter, and the chief nutrient of potatoes and rice is starch. Each of these materials is unfit by itself for nourishment. Milk, on the other hand, abounds in all the nutrients and is more nearly a "perfect food," for those with whom it agrees, than any other animal food material. While meats and fish are rich in protein, and most meats and some fish abound in fats, the vegetable foods generally lack protein and fats but have an excess of carbohydrates, of which the meats and fish have none. Beans and pease, however, have a good deal of protein.

We have here a very simple chemical explanation of a usage which, under the promptings of experience or instinct, mankind has almost everywhere come to adopt,—that of supplementing wheat and corn and rice and potatoes with meats and fish, or, when these are lacking, by beans, pease, or other vegetables rich in protein. There is a sound reason in the Hindu's practice of eating pulse with rice, in the Irishman's use of skimmed milk with his potatoes, in the Scotchman's

* The following is from the late report of the Dairy Commissioner of Connecticut, which comes to hand just as this is being written:

"As a protection to consumers the national law is a failure, and the present tax is too small to benefit our dairies to any appreciable extent; a ten cent tax

might more nearly have accomplished what the national law was intended to accomplish, but as matters now stand the national law is simply a source of revenue to the national government, and practically levies a tax on poor people who can ill afford to bear it."

partiality for oatmeal, haddock, and herring, and in the frugal New England diet of cod-fish and potatoes and pork and beans.

Reserving further consideration of these subjects for future articles, I may briefly recapitulate some of the main points already considered.

First. Our bodies and our foods consist of essentially the same kinds of materials.

Second. The actually nutritive ingredients of our food may be divided into four classes: protein, fats, carbohydrates, and mineral matters. Leaving water out of account, lean meat, white of egg, casein (curd) of milk, and gluten of wheat consist mainly of protein compounds. Butter and lard are mostly fats. Sugar and starch are carbohydrates.

Third. The nutrients of animal foods consist

mainly of protein and fats. Those of the vegetable foods are largely carbohydrates. The fatter kinds of meat and some species of fish, as salmon, shad, and mackerel, contain considerable quantities of fat. The lean kinds of meat and such fish as cod and haddock contain very little fat. Beans, pease, oatmeal, and some other vegetable foods contain considerable quantities of protein.

Fourth. The different nutrients have different offices to perform in the nutrition of the body. The demands of different people for nourishment vary with age, sex, occupation, and other conditions of life. Health and pecuniary economy alike require that the diet should contain nutrients proportioned to the wants of the user.

W. O. Atwater.

IF.

IF he had known that when her proud fair face
Turned from him calm and slow
Beneath its cold indifference had place
A passionate, deep woe.

If he had known that when her hand lay still,
Pulseless so near his own,
It was because pain's bitter, bitter chill
Changed her to very stone.

If he had known that she had borne so much
For sake of the sweet past,
That mere despair said, "This cold look and
touch
Must be the cruel last."

If he had known her eyes so cold and bright,
Watching the sunset's red,
Held back within their deeps of purple light
A storm of tears unshed.

If he had known the keenly barbéd jest
With such hard lightness thrown
Cut through the hot proud heart within her
breast
Before it pierced his own.

If she had known that when her calm glance
swept
Him as she passed him by
His blood was fire, his pulses madly leapt
Beneath her careless eye.

If she had known that when he touched her
hand
And felt it still and cold
There closed round his wrung heart the iron
band
Of misery untold.

If she had known that when her laughter rang
In scorn of sweet past days
His very soul shook with a deadly pang
Before her light dispraise.

If she had known that every poisoned dart —
If she had understood
That each sunk to the depths of his man's heart
And drew the burning blood.

If she had known that when in the wide west
The sun sank gold and red
He whispered bitterly, "'Tis like the rest;
The warmth and light have fled."

If she had known the longing and the pain,
If she had only guessed,—
One look — one word — and she perhaps had
lain
Silent upon his breast.

If she had known how oft when their eyes met
And his so fiercely shone,
But for man's shame and pride they had been
wet—
Ah! if she had but known!

If they had known the wastes lost love must
cross,—
The wastes of unlit lands,—
If they had known what seas of salt tears toss
Between the barren strands.

If they had known how lost love prays for
death
And makes low, ceaseless moan,
Yet never fails his sad, sweet, wearying
breath—
Ah! if they had but known.

Frances Hodgson Burnett.

HOW FOOD NOURISHES THE BODY.

THE CHEMISTRY OF FOODS AND NUTRITION. II.

"These problems, which are of such great importance for physiology, for medicine, and for social economy, cannot be solved without untiring patience and very considerable means."—*Voit*.



"Eat to live." The eating of bread and meat is a simple matter, but the ways in which the different constituents of the food perform their offices in the maintenance of life are problems as profound as any with which physical science has to deal. The works of nature culminate in man. In his organism her operations are most complex and recondite. The laws which regulate our physical being are discovered but slowly and by the most ingenious and profound research. Those which govern the nutrition of our bodies have been shrouded in mystery which only the investigation of later time has begun to unveil. But, here as elsewhere, the crude and often fantastic theories of the past are being gradually replaced by the more certain knowledge of the present.

In the previous article we noticed the chemical composition of the human body and of the

food by which it is nourished. It appeared that our bodies and our food both are composed of the same chemical elements, and that the compounds of these elements which chemical analysis reveals in the food are likewise very similar to the compounds of which our bodies are composed. This, indeed, we should expect from the very fact that the body is made of the food.

The reproduction below of a chart from the previous article of this series describes the principal constituents of our foods. The proportions of the several ingredients in a number of food-materials are shown in Diagram III. of the previous article.

But the food does more than to furnish the material of which the body is built up. As our tissues, muscle and tendon, bone and brain, are continually worn out with work and thought and worry, it is with the ingredients of food that they are repaired, and it is our food that supplies the fuel by whose consumption the heat and strength of the body are maintained.

INGREDIENTS OF FOOD-MATERIALS.

NUTRIENTS AND NON-NUTRIENTS.

Our ordinary food-materials, such as meat, fish, eggs, potatoes, wheat, etc., consist of:

REFUSE: *E. g.*, the bones of meat and fish, shells of eggs, skin of potatoes, and bran of wheat.

EDIBLE PORTION: *E. g.*, the flesh of meat and fish, whites and yolk of eggs, wheat flour.

The edible substance consists of:

WATER,

NUTRITIVE INGREDIENTS OR NUTRIENTS.

The principal kinds of nutrients are:

1. PROTEIN,
2. FATS,
3. CARBOHYDRATES,
4. MINERAL MATTERS.

The water and refuse are called non-nutrients. The water contained in foods and beverages has the same composition and properties as other water, and it is, of course, indispensable for nourishment, but is not a nutrient in the sense in which the word is here used.

CLASSES OF NUTRIENTS.

The following are familiar examples of compounds of each of the four principal classes of nutrients:

- | | | |
|-----------------|---|---|
| PROTEIN | { | <p><i>a</i> ALBUMINOIDS: Albumen (white) of eggs; casein (curd) of milk; myosin, the basis of muscle (lean meat); gluten of wheat, etc.</p> <p><i>b</i> GELATINOIDS: Collagen of tendons; ossein of bones; which yield gelatin or glue.</p> |
| FATS | { | <p><i>E. g.</i>, fat of meat; fat (butter) of milk; olive oil; oil of corn, wheat, etc.</p> |
| CARBOHYDRATES | { | <p><i>E. g.</i>, sugar, starch, cellulose (woody fiber).</p> |
| MINERAL MATTERS | { | <p><i>E. g.</i>, calcium phosphate, or phosphate of lime; sodium chloride (common salt).</p> |

It is to be especially noted that the protein compounds contain nitrogen, while the fats and carbohydrates have none. Meats and fish contain very small quantities of a class of compounds called "extractives" (the chief ingredients of beef tea and meat extract), which contain nitrogen, and hence are commonly classed with protein. The albuminoids and gelatinoids are sometimes called proteids.

The physiological chemistry of to-day looks upon the body as a sort of machine. Food is the raw material; heat, muscular strength, and other forms of energy are the products. But this does not exactly express the idea; for both the machine and its products come from the transformation of the food, and furthermore, the body is continually consuming not only food but its own substance also, in order to generate heat to keep itself warm, and muscular and intellectual energy to do its own work.

The particular question I wish to speak of now is this: What parts do the several classes of nutrients of food, the protein, fats, carbohydrates, etc., play in the nutrition of the body? Or, to put it in another way, of what constituents of the food are flesh and fat made up, what ones supply us with warmth and muscular strength, and what are the chemical transformations which our nutriment continually undergoes in supplying our bodily wants? These transformations belong to what the physiologists are teaching us to call metabolism. It is a part of this subject of metabolism that we have now to consider.

When we know what are the kinds and amounts of nutritive substances our bodies need and our food-materials contain, then and not till then shall we be able to adjust our diet to the demands of health and purse.

The ways in which the body makes use of its food are found out by experiments made with living animals, with pigeons, geese, rabbits, dogs, sheep, goats, oxen, horses and many others, including men. The experimenting of the last few years, particularly, has been very extensive, and has brought extremely important results. To give a brief account of some of these researches and their principal results as applied to the nutrition of man is the object of this article. Will the reader first permit a few technical statements which seem necessary by way of introduction?

If we could follow the course of a molecule of the protein of the meat we eat from the time when, after being digested, it is taken into the blood, and carried and stored in the arm as muscle and afterwards consumed; if we were gifted with vision acute enough to trace the journeyings and transformations of a particle of the fat of the same meat or of the starch of the bread eaten with it, until it is deposited as fat in the muscle or in adipose tissue, or is disintegrated and united with the oxygen of the inhaled air, yielding warmth or strength, the answer to our questions as to how the different nutrients do their work might be made very plain. But vitally important as these processes are, near as they are to us, parts as they are of us, they have been almost entirely beyond our ken until late experimental re-

search has found a practicable way for learning about them. This way of finding how food is used consists in the comparison of the income with the outgo of the body.

The body creates nothing for itself, either of material or energy; all must come to it from without. Every atom of carbon, hydrogen, phosphorus, or other elements; every molecule of protein, carbohydrates or other compounds of these elements, is brought to the body with the food and drink it consumes and the air it breathes. Like the steam-engine, it simply uses the material supplied to it. Its chemical compounds and its energy are the compounds and the energy of the food transformed.

The science of nutrition as it is taught to-day has this marked peculiarity, that it is a matter of definite quantities of income and expenditure, measured in terms of chemical elements and compounds, and of heat and mechanical energy. It is based upon a kind of chemical book-keeping, and the accuracy of its teaching is, in a certain sense, proportional to the accuracy with which the accounts are kept. The items of the account are obtained from experiments with living organisms, with animals fed upon different food-materials, under circumstances and with appliances which render feasible the accurate measurement of income and outgo.

DAILY INCOME AND EXPENDITURE OF THE BODY.—METABOLISM.

Food, drink, and oxygen of inhaled air constitute the income of the body. Part of this material is transformed into blood, muscle, fat, bone, and other tissues. The rest, together with the materials worn out with use, undergo still further chemical transformations. The compounds thus formed are finally given off from the body and constitute its outgo, or expenditure of material.

A small part of the food passes through the alimentary canal undigested and is excreted by the intestine. The larger part is digested, taken into the blood, and distributed through the body. Some of it is used to build up tissues, as in the case of the growing child; some is used to repair the tissues that are being continually disintegrated; but ultimately the oxygen brought from the air through the lungs unites with the carbon and hydrogen of the food or of the tissues consumed, forming carbonic acid and water, while the nitrogen with part of the carbon and hydrogen forms urea and similar products. The urea and allied compounds escape by way of the kidneys, the carbonic acid is given off by the lungs and skin, and the water by the lungs, skin, and

kidneys. So, since tissues are made up of the food, practically all of the digested protein, fats, and carbohydrates finally leave the body as urea, carbonic acid, and water.

Let us take, for instance, the case of an ordinary man, say a mechanic or a day-laborer, doing a fair amount of manual work. Let us suppose him to have a diet of beefsteak, bread, potatoes, butter, and water. To simplify the calculations, we will leave out the tea, coffee, salt, etc., and take enough of the bread and potatoes to make up for the milk, sugar, and other materials which he would ordinarily consume. Such quantities as the following would supply the necessary nutrients for a day:

| | |
|---|-----------|
| Beefsteak (lean and free from bone) | 8 ounces. |
| Bread | 20 " |
| Potatoes | 30 " |
| Butter | 1 " |
| Water | 37 " |

Total food and drink. . (6 pounds) 96 ounces.

With these six pounds of food and drink he would consume about 30 ounces of oxygen from the air inhaled during the twenty-four hours, making a total income not far from 126 ounces, or 7 $\frac{7}{8}$ pounds.

But in our chemical balancing of income and expenditure the calculations are made, not in terms of meat and bread and butter, but of protein, fats, carbohydrates, etc. It may be drawn up as below: I give weights in grams as well as in ounces, since we shall find the grams convenient in subsequent calculations.

The experiments I am about to describe are based upon the principle involved in this supposed case. A large number of most important ones have been performed in Germany, in nu-

merous agricultural experiment stations with animals and, in Munich, with men as well.

EXPERIMENTS FOR STUDYING THE LAWS OF NUTRITION.

THE hurried visitor in Munich, after seeing the treasures of painting and sculpture in the Old and the New Pinakothek and the Glyptothek, is apt to drive to the statue of Bavaria, outside the town. In doing so he will very likely pass a house—it is a square, gray, and somewhat gloomy building just across the street from the Crystal Palace—which to the chemist, the physiologist, the agriculturist, and the student of political and social science is of no little interest, for here lived and labored for many years the great philosopher Liebig, who is, more than any other man, the father of the science we are studying. Going on across the Marien Platz with its quaint Renaissance buildings and out through the Sendlinger gate, he passes along the Findling Strasse. On the right, just beyond the gate, is a brick building which the artistic traveler will not be apt to notice, but which to those interested in our present subject is full of attraction. It is the Physiological Institute of the university. In it are the laboratory and respiration apparatus where Pettenkofer, Voit, and others have conducted some of the most important researches in this department of science. If the reader wished to see how some of the facts of modern science are found out, I should hardly know of a more interesting place to which to take him than this.

Coming in through the hallway, we have, on the right, the apartments of the *Hausmeister*, who is at once the chief janitor and the mechanic of the establishment, and on the left,

| ASSUMED DAILY INCOME AND EXPENDITURE OF THE BODY OF AN AVERAGE MAN DOING A MODERATE AMOUNT OF MUSCULAR LABOR. | | | |
|---|--|--|--|
| INCOME. | | OUTGO. | |
| Materials. | Weights, Expressed in ounces. Expressed in grams.* | Materials. | Weights, Expressed in ounces. Expressed in grams.* |
| Nutrients of food { Protein | 4.2 118 | From digested food and inhaled oxygen { Respiratory products excreted through lungs and skin . . . { Carbonic acid | 38.8 1100 |
| { Fats | 2.0 56 | { Water | 12.7 361 |
| { Carbohydrates | 17.6 500 | { Urea, etc. | 1.2 34 |
| { Mineral matters | 0.8 24 | { Excreted by kidneys { Mineral matters | 0.7 20 |
| Water of food and drink | 71.4 2024 | Water otherwise excreted | 71.4 2024 |
| Oxygen of inhaled air | 30.2 855 | Undigested matters (water free) | 1.4 38 |
| Total | 126.2 3577 | Total | 126.2 3577 |

* One pound, avoirdupois, 453.6 grams; one ounce, 28.35 grams.

rooms for the assistants and for some of the laboratory work, while a stairway leads to the lecture and apparatus rooms above. A door in front opens into the main working-room, which is fitted up like an ordinary chemical laboratory. At different desks assistants and students are at work, and we perhaps see the burly form of the *Diener*, the laboratory servant, with whom a large number of experiments have been made.

At the left is a room supplied with a number of curious-looking cages. In one may be a dog, in another a goose, and in a third a number of rats, all being used for feeding-trials of one kind or another. In the rear are the balance-room, the study of Professor Voit, director of the establishment, and, what is most interesting of all to us, the respiration apparatus.

Before explaining the respiration experiments, which are somewhat complicated, let me describe a simpler experiment, taking one actually made to study the effect of protein in the form of lean meat, *i. e.*, muscle.

The question was this: From a given quantity of the protein of muscular tissue, how much will be digested by a healthy man, and will the quantity digested suffice to maintain the supply of protein in his body? In other words, will the man gain or lose protein, or will he simply hold his own on this diet?

The subject was a medical student. The experiment lasted three days. For protein he ate very lean beefsteak. This contained, along with the protein, a little fat (the fat was trimmed out as carefully as practicable, but nevertheless minute particles remained about and within the muscular fibers of the meat), and mineral matters, besides, of course, considerable water. The diet consisted of the beefsteak cooked with butter, seasoned with pepper, salt, and Worcestershire sauce, and taken with water, beer, and wine.

Leaving the other materials out of account, as they did not essentially affect the results, the food contained 1200 grams, about 2 pounds 10 ounces, of the lean meat, and 30 grams, or a little over an ounce, of butter per day. The total quantity of nitrogen in the food was about 38 grams daily, of which over 37 grams were digested. It is mainly upon this nitrogen that the experiment hinges.

One of the hard-fought questions of physiological chemistry has been whether or not all of the nitrogen given off from the body (aside from that which is undigested) is excreted by the kidneys. But it is now pretty well settled that this is the only way by which any considerable quantity leaves the body. If then we know how much nitrogen is digested and taken into the circulation and how much is withdrawn in this way, we have an easy

means of determining whether the stock of nitrogen in the body is gaining or losing. If I put more money in the bank than I draw out, my balance on the books shows an increased amount to my credit; but if I take out more than I put in, my deposit grows smaller. In like manner the balance of income and outgo of nitrogen shows whether the body is gaining or losing nitrogen.

Now for this purpose we may regard the compounds of the body, exclusive of water and mineral matters, as belonging to two classes — protein compounds and fats. And numerous as the protein compounds are, the proportion of nitrogen is nearly the same in all, and we may take the protein of muscle as representing the whole class. For every gram of nitrogen there will be just about $6\frac{1}{4}$ grams of protein, and for every gram of protein there will be about $4\frac{1}{3}$ grams of muscle, tendon, and the like in meat. Accordingly, for every gram of nitrogen there will be ($6\frac{1}{4} \times 4\frac{1}{3}$) about 27 grams of muscle, exclusive of fat.

The question, then, may be put thus: On the diet of 2 pounds and 10 ounces of lean meat and an ounce of butter per day, was the store of protein in this man's body increased or decreased? In other words, so far as muscular tissue was concerned did he gain or lose or hold his own? Here are the figures:

INCOME AND OUTGO OF DIGESTED NITROGEN IN EXPERIMENT WITH A MAN ON DIET OF LEAN MEAT.

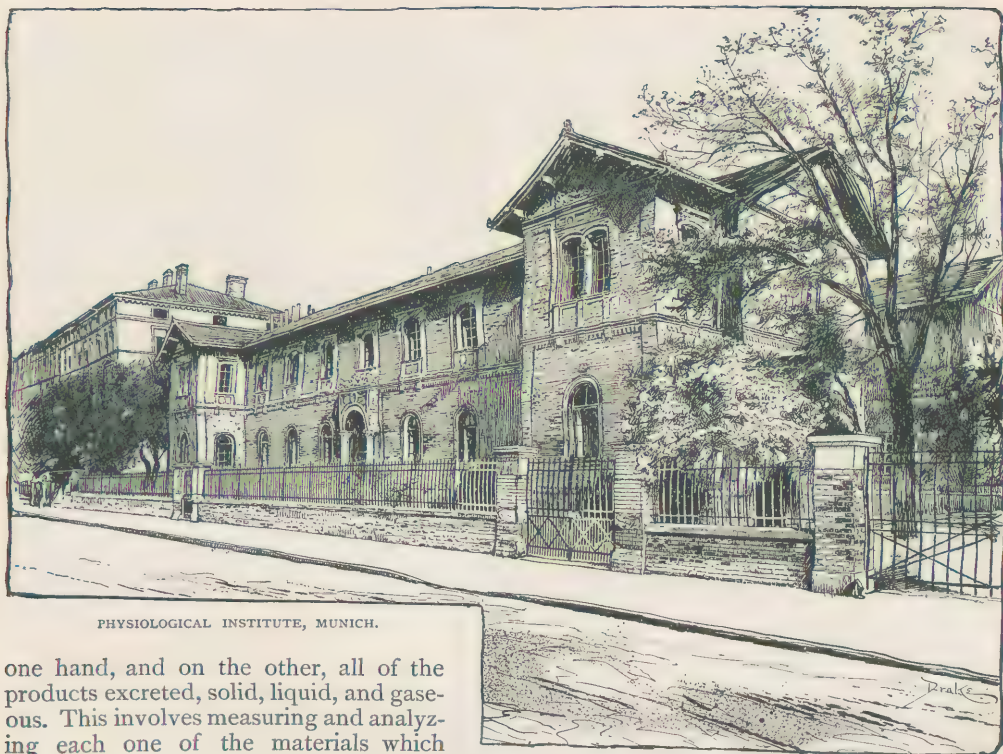
| | | |
|---------------------|-------------|--------------|
| Total nitrogen..... | per day | .38.5 grams. |
| Nitrogen..... | kidneys “ “ | 37.2 “ |

Balance, stored in the body “ “ 1.3 grams.

That is to say, this young, vigorous man, a student, at his ordinary occupations, studying in his room, listening to lectures at the university, working several hours each day in the laboratory, walking a little for exercise, and living on a diet of protein with a very little fat, gained nitrogen at the rate of 1.3 grams per day. These 1.3 grams of nitrogen represented about 8.2 grams of protein or 35 grams ($1\frac{1}{4}$ ounces) of muscle gained per day during the three days of the experiment. In other words, so far as the lean flesh in his body was concerned he just a little more than held his own.

But what about the fat of his body — did he gain or lose? Did the protein and fat of the meat and butter suffice still further to supply him with heat and muscular energy, or did he consume some of the fat previously stored in his body?

The only way to answer the question is to measure exactly all of the income and the outgo of the body — the food and drink on the



PHYSIOLOGICAL INSTITUTE, MUNICH.

one hand, and on the other, all of the products excreted, solid, liquid, and gaseous. This involves measuring and analyzing each one of the materials which made up the food and drink, and at the same time all of the products excreted by the intestines, kidneys, lungs, and skin. In brief, we must, with the rest, measure the compounds given off as vapor or gas. With them, the account of income and outgo will be complete.

But this means that we must measure and analyze the inhaled and exhaled air.

THE RESPIRATION APPARATUS.

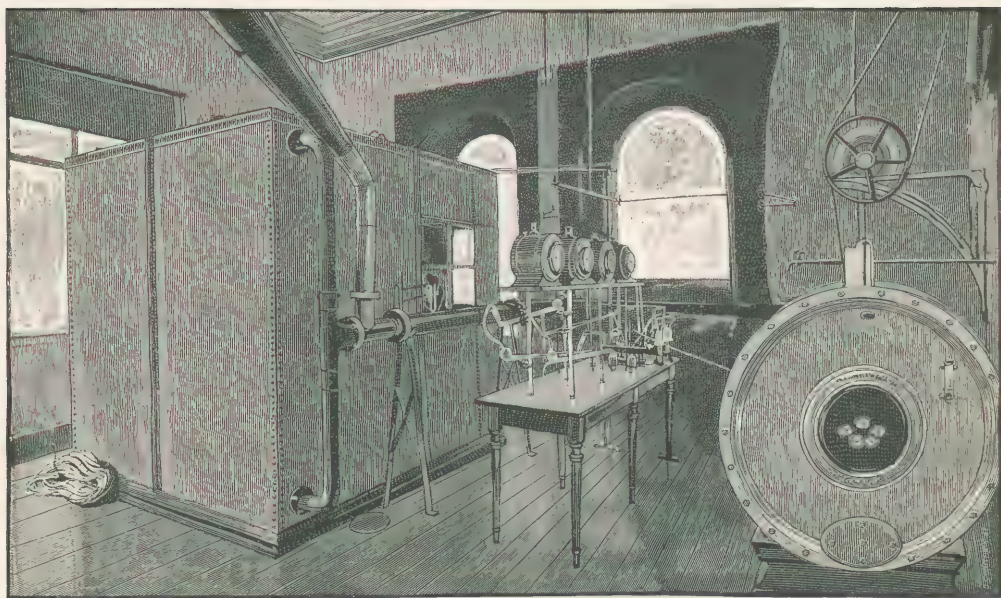
THE respiration apparatus is a device for measuring the respiratory products. Many forms have been devised, from one in which the products of respiration of a piece of muscle taken from a just-killed animal can be measured, the respiratory process being maintained by artificial circulation of blood through the muscle, to one in which an ox may be kept for days or weeks, and the composition of the inhaled and exhaled air likewise determined.

A very interesting form is that used by the French experimenters, Regnault and Reiset. This is a small chamber of glass, inside of which the animal is placed, some rather complicated appliances being used to continually renew the supply of oxygen and remove the carbonic acid and other products of respiration. But from insufficient ventilation and other minor difficulties, this form of apparatus has not quite sufficed for satisfactory experiments, especially with the larger animals and with man.

By far the most satisfactory apparatus is that invented by Professor Pettenkofer of Munich. This, to my notion, is one of the most interesting devices of modern experi-



PROFESSOR PETTENKOFER.
(FROM A PHOTOGRAPH BY F. MULLER.)



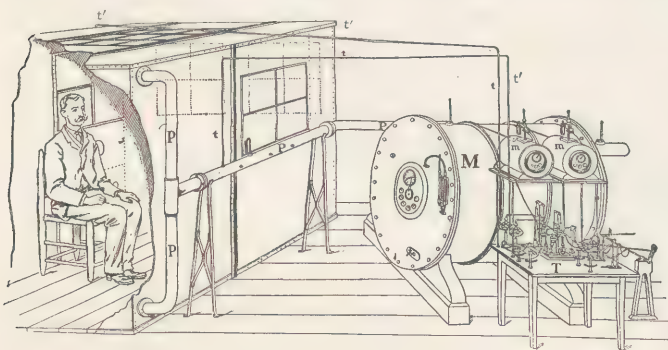
PETTENKOFER'S RESPIRATION APPARATUS.

mental science. The first one was built through the munificence of the King of Bavaria.

The peculiar features of this apparatus are that the subject of experiment, be it a dog, an ox, or a man, is in a comfortable, well-ventilated room, and that the air, which passes through it in a continuous current, is measured and is analyzed both before it goes in and after it comes out. We can thus tell just what the animal has added to it, in other words, what material has been given off as gas or vapor from the body. The arrangements do not provide for estimating all the respiratory products with absolute exactness, but they suffice for reasonably accurate results. The form used for experiments with man consists of a chamber — a *salon*, it is called; as a matter of fact it is an iron box — through which a cur-

rent of air is drawn by a large pump, the latter being worked by an engine.

The *salon* of the large apparatus at Munich is made of plates of iron, similar to boiler-iron, and is in the form of a cube about eight feet each way. It has glass windows, and a door large enough to admit a man. The large engraving herewith shows the apparatus as it is now arranged. On the left is the chamber in which the man under experiment stays; near are a table holding apparatus for analyzing the air before and after it passes through the chamber, and a large meter for measuring the quantity of air which passes through. In an adjoining room is the machinery by which the current of air is pumped through the apparatus. The smaller sketch explains the working in more detail. The air enters the chamber at its left side and passes out on the right



DETAIL DRAWING OF ABOVE.

through the large pipe P P, into the large meter M, in which it is measured. A small tube, t t, takes from the pipe P P a portion of the air which has been passed through the chamber and contains the products of respiration into two small meters, m m, where it is measured, and through the apparatus on the table T, where it is analyzed. A similar small tube, t' t', brings air for analysis from the outside of the apparatus, taking it from the left of the chamber

where it enters the latter and carrying it into two other small meters (not shown in this sketch), where it is measured, and through apparatus, also not shown here, by which it is analyzed. In the larger engraving the four small meters and apparatus for analyzing the air are shown on the table between the chamber and the large meter. Comparisons of the quantity and composition of the air which has passed through the chamber with the outside air show what the man has imparted to the air in breathing, and thus tell the amounts of the products of respiration. The food and drink and the solid and the liquid products of its consumption in the body are at the same time measured, weighed, and analyzed, and thus all of the items of income and outgo of the body are determined.

The first man to enter the respiration apparatus for experiments upon himself, I believe, was Professor Ranke of Munich, who has described his experiences in his book on "The Nutrition of Man" ("Die Ernährung des Menschen"), as well as in special memoirs. He tells us that in trials in which he took no food the fasting was somewhat disagreeable, but far less painful than many would think. "I found myself at the end of the first 24 hours entirely well; at the end of the second 24 hours without food or drink, during which sleep had been disturbed, the head was somewhat heavy and there was an oppressiveness in the stomach and considerable weakness; but the sensation of hunger, . . . which was strongest about 30 hours after the last food was taken, . . . did not appear any more."

In the greater number of Professor Ranke's experiments he took a reasonable amount of food. The diet was simple, and consisted of such materials as lean meat, bread, white of egg, starch, sugar, butter, etc., and was found to serve the purpose very well. After some experience a ration was arranged which corresponded very well in composition with that used by ordinary working people, and was at the same time not at all unacceptable. When a number of experiments with Professor Ranke had been completed, several series were made with other persons. One of these latter series I will briefly describe.

The subject was a strong, healthy mechanic, a watchmaker, 28 years old and weighing about 156 pounds. Three experiments were made, each occupying 24 hours. In the first,

the man took nothing but a little meat extract, salt, and water, and did no work. In the second, he had a liberal allowance of palatable food, but still remained at rest. In the third, he had the same diet as in the second, but worked hard at turning a lathe for nine hours, so that he was thoroughly tired at night. During the daytime of the first two experiments, I should say, he read, cleaned a



PROFESSOR VOIT. (FROM A PHOTOGRAPH BY F. MULLER.)

watch, and otherwise occupied himself to while away the time, making, however, very little muscular effort.

The three experiments, then, show the effects of fasting and rest, food and rest, and food and muscular exercise upon the income and outgo of this man's body. We will note only very briefly some of the details of the experiments, the full accounts of which fill many pages.

The diet of the first experiment consisted of:

Meat extract, 12.5 grams (a little less than one-half ounce).
Salt, 15.1 grams (a little over one-half ounce).
Water, 1027.2 grams (about a quart).

The day's ration of the second trial included a third of a pound of lean meat, a pound of bread, a little over a pint of milk, and about a quart of beer, and other materials as follows:

DAY'S FOOD IN SECOND EXPERIMENT.

| | | |
|----------------------------|------|--------|
| Meat, lean beef..... | 140 | grams. |
| Egg albumen (white of egg) | 42 | " |
| Bread..... | 450 | " |
| Milk..... | 500 | " |
| Beer..... | 1025 | " |
| Lard..... | 70 | " |
| Butter..... | 30 | " |
| Starch..... | 70 | " |
| Sugar..... | 17 | " |
| Salt..... | 4 | " |
| Water..... | 286 | " |

The diet of the third experiment was essentially the same as that of the second, except that the man drank a little more water.

The income included, besides the food and drink, the oxygen consumed from the inhaled air. The estimated quantities were :

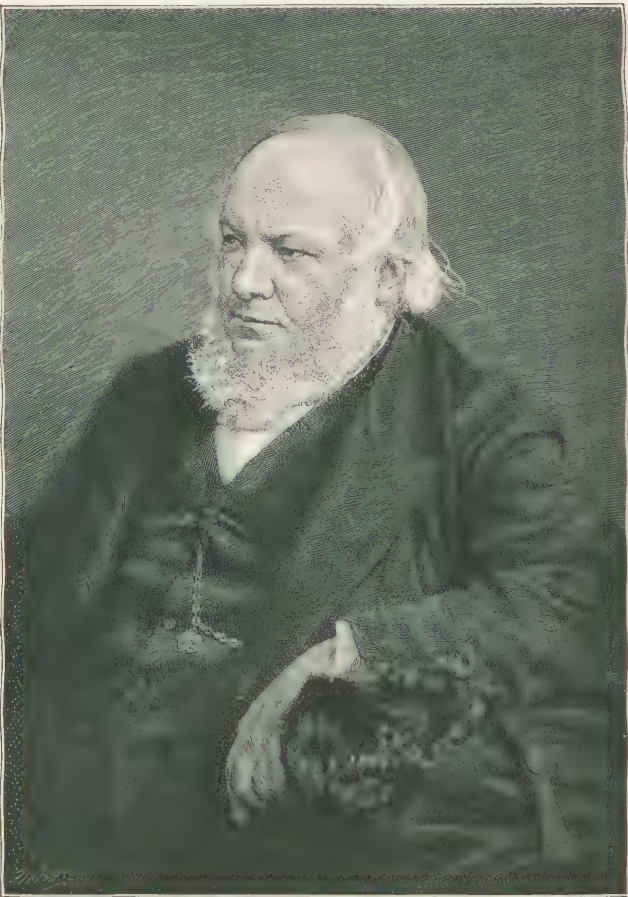
Oxygen used in 24 Hours.

- First experiment, fasting and at rest, 779 grams.
- Second experiment, liberal ration and at rest, 709 grams.
- Third experiment, liberal ration and at work, 1006 grams.

The final balance-sheets of the experiments, which show the details of income and outgo in terms of the chemical elements, carbon, nitrogen, etc., are too extensive to be reported here. That for each experiment would nearly fill one of these pages, but as some readers may be curious to see what they are, I give the principal data in abbreviated form.*

DAILY INCOME AND EXPENDITURE OF CHEMICAL ELEMENTS.

| | Carbon. | Hydrogen. | Nitrogen. | Oxygen. |
|--|---------|-----------|-----------|---------|
| | Grams. | Grams. | Grams. | Grams. |
| Experiment with no food (except meat extract) and no work: | | | | |
| Income | 2.4 | 115.1 | 1.2 | 1698.4 |
| Outgo | 209.5 | 221.6 | 12.5 | 2301.4 |
| Loss | 207.1 | 106.5 | 11.3 | 603.0 |
| Experiment with liberal ration of meat, milk, bread, etc., and no work: | | | | |
| Income | 315.5 | 270.9 | 19.5 | 2712.9 |
| Outgo | 275.7 | 248.2 | 19.5 | 2630.2 |
| Gain..... | 39.8 | 22.7 | 0.0 | 82.7 |
| Experiment with liberal ration, as in preceding experiment, and hard work: | | | | |
| Income | 309.2 | 297.7 | 19.5 | 3232.5 |
| Outgo | 330.3 | 304.9 | 19.5 | 3246.5 |
| Loss..... | 27.1 | 7.2 | 0.0 | 14.0 |



PROFESSOR MOLESCHOTT. (FROM A PHOTOGRAPH BY C. LE LIEURE.)

But we wish to know what quantities of flesh and fat the man gained or lost under these different conditions of food and fasting, labor and rest. The figures just cited are for the chemical elements of which the protein and fats are composed. Knowing the propor-

* The accuracy of these experiments has been occasionally called in question, especially on the ground that with the possible sources of error, so complete an accuracy in the balance-sheet is in itself suspicious.

That some of the chemical work involved in the researches of which these form a part might have been performed by more nearly perfect methods is doubtless true, but I believe that experience in the Munich laboratory and careful examination of the published details of the researches must convince the most exacting physiological chemist that such criticisms are without foundation. As regards the chief subject of criticism, which is connected with the question of "nitrogen balance," it will suffice to say that the tendency of the latest investigations has been to very decidedly confirm the correctness of the assumption on which the Munich results are based, *i. e.*, that practically all the digested nitrogen is excreted by the kidneys. And certainly all the men I have known among those who have worked in the Munich laboratory regard the complete accuracy above alluded to as the result of careful and thoroughly reliable work.

tions of the elements in each compound, it is easy, from the figures for the elements, to estimate the quantities of the compounds. Omitting details of the calculations* the results are given in the balance-sheet of compounds herewith. Regarding the carbohydrates, however, I should explain that since the body has extremely little of its own, and those of the food are consumed, they are left out of account in the experiment without food, and the amounts received and consumed in the experiments with food are taken as balancing one another.

work, with the same amount of food, he likewise held his own so far as lean flesh was concerned, but lost two ounces of fat. The body used for its support protein and fats, in each case, and carbohydrates when it had them. When the nutrients were not supplied in food, it consumed a little protein and a good deal more fat from its own store. With a ration which sufficed to exactly maintain its protein without gain or loss, the body gained fat when it had only a little more than its own muscular work to perform (that in-

INCOME AND EXPENDITURE OF CHEMICAL COMPOUNDS BY BODY OF MAN.

| | Fasting. No work. | | | Liberal ration. No work. | | | Liberal ration. Hard work. | | |
|-------------------------|-------------------|--------|---------------------|--------------------------|--------|---------------------|----------------------------|--------|---------------------|
| | Protein. | Fats. | Carbo- hydrates. | Protein. | Fats. | Carbo- hydrates. | Protein. | Fats. | Carbo- hydrates. |
| | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Income | 7 | 0 | none | 122 | 117 | 332 | 122 | 117 | 352 |
| Outgo | 78 | 216 | none | 122 | 52 | 332 | 122 | 173 | 352 |
| Gain, + or loss — | —71 | —216 | none | 0 | +65 | 0 | 0 | —56 | 0 |

The protein gained or lost was mainly from the muscles and similar tissues, or what we may call flesh as distinguished from fat. Taking the figures for protein and fats gained and lost as shown in the last line of the balance-sheet of income and expenditure of compounds, changing grams to ounces, and assuming that with each ounce of protein would be water, etc., enough to make the equivalent of $4\frac{1}{2}$ ounces of lean flesh, *i. e.*, muscle, tendon, etc., we have this final result of the trials; the quantities, as before, are those gained or lost in one day:

OUTCOME OF THE EXPERIMENTS AS REGARDS INCREASE OR DECREASE OF LEAN FLESH AND FAT WITHIN THE BODY.

| | Lean flesh (muscle, etc.). | Fats. |
|------------------------------------|-------------------------------|-----------------------|
| No food, no work, loss..... | 11 ounces | $7\frac{1}{2}$ ounces |
| Liberal diet, no work, gain..... | none | $2\frac{1}{3}$ " |
| Liberal diet, hard work, loss..... | none | 2 " |

That is to say, fasting, and without muscular labor, the man lived upon the tissues of his body, and consumed daily a trifle less than three-quarters of a pound of muscle, and with this nearly half a pound of the fat previously stored in his body. With plenty of food, and still resting, he neither gained nor lost lean flesh, but gained $2\frac{1}{3}$ ounces of fat in a day. And when he set himself to hard muscular

work, with the same amount of food, he likewise held his own so far as lean flesh was concerned, but lost two ounces of fat.

If we had only these experiments to judge from, we might infer that muscular energy comes from consumption of fat, and that the special work of the protein of the food is to repair the wastes and make up for the wear and tear of the protein of the body; and this would be true as far as it goes. But, of course, many other experiments and of many different kinds are needed to settle these questions. The majority of the most useful ones, thus far, have been made with other animals than man. For experiments with dogs, geese, and other small animals a small respiration apparatus on the plan of Professor Pettenkofer's has been devised by Professor Voit.

In studying the laws of animal nutrition the most convenient organism, for many purposes, is that of the dog. The dog thrives upon both animal and vegetable foods, utilizes large quantities of food to advantage or endures long fasting with patience, and makes ready responses by changes of bodily condition to changes in the food. In reading the accounts of the famous feeding-trials conducted by Bischoff and Voit, one is surprised to see what control they obtained of the organisms of the dogs experimented with. By altering the kinds and quantities of food constituents, Voit was able either to reduce both the flesh (protein) and the fat of the animal's body or to increase

*The calculations, based upon accepted principles of physiological chemistry, are too complex for this place. They are to be explained in detail in a book on

this general subject now in preparation. Students may find them in the original (German) memoirs in which the experiments are described.

both flesh and fat, or to reduce the one or to increase the other. Indeed, the manipulations effected in this way seemed almost equivalent to getting into the tissues and directly removing or adding flesh, or fat, at will. The principles thus learned from experiments with the dog and other animals apply in the main, though not in all the details, to the nutrition of man.

But I must beware of burdening the reader with details, a danger he will appreciate when I say that the experiments of the last twenty years are numbered by hundreds and even thousands, and that the literature of the subject is so voluminous that few specialists even are able to handle it. I will endeavor to very briefly summarize a few of the main results. I do not know how to do this better than in the following chart, which was prepared for the Food Collection of the National Museum.

USES OF FOOD IN THE BODY.

Food supplies the wants of the body in several ways.

Food furnishes:

1. The material of which the body is made.
2. The material to repair the wastes of the body, and to protect its tissues from being unduly consumed.

Food is consumed as fuel in the body to:

3. Produce heat to keep it warm.
4. Produce muscular and intellectual energy for the work it has to do.

The body is built up and its wastes are repaired by the nutrients. The nutrients also serve as fuel to warm the body and supply it with strength.

WAYS IN WHICH THE NUTRIENTS ARE USED IN THE BODY.

The Protein of food { forms the nitrogenous basis of blood, muscle, sinew, bone, skin, etc.
is changed into fats and carbohydrates.
is consumed for fuel.

The Fats of food { are stored in the body as fat.
are consumed for fuel.

The Carbohydrates of food { are changed into fat.
are consumed for fuel.

The Mineral matters of food { are transformed into the mineral matters of bone and other tissues.
are used in various other ways.

Like all attempts to tell a long story in a few words, it omits many important details and gives incomplete expression to the facts which it states. Thus, regarding the use of the nutrients as "fuel," although their elements combine with oxygen as those of the coal and wood do in the stove, the process, as it actually goes on in the body, is far more complex and less completely understood. In saying

that food yields muscular and intellectual energy the statements do not explain how this is done, nor has science yet given an at all complete explanation of these wonderful phenomena. Nor do these statements include the important fact that the fats, protein, and other substances stored in the body are used like those of the food. But the chart includes what it is most important for our present purpose to remember, and we shall have occasion to make further explanations in another place.

Translating the statements of this chart into ordinary language, it means that, when we eat meat and bread and potatoes and other kinds of food, our bodies use the nutritive ingredients in different ways. Thus the myosin, which is the principal nutritive ingredient of muscle (lean meat), the casein (curd) of milk, the albumen (white) of egg, and the gluten of bread are all albuminoids or protein compounds, and are transformed into muscle, tendon, and other nitrogenous materials in our bodies. The protein compounds are sometimes called flesh-formers, which is all very well so far as it goes, but does not go far enough. They, and they alone, form flesh (*i. e.*, nitrogenous tissue), it is true, but they do a good deal more. They are also transformed into fat and carbohydrates in our bodies, and they are consumed as fuel to yield us heat and muscular strength.

But our meat always contains more or less fat. This may be taken up by the body and stored as fat within the muscle, bone, and adipose or other tissues, and so retained for a time as a part of the body-fat; but the bulk of the fat of the food serves as fuel, and that which has been stored in the body is consumed for the same purpose when occasion demands. Thus the man in the experiments above described lived on the fat previously stored in his body when he took no food; laid up fat when he had a liberal ration and did no work; and drew upon the accumulated store again when he did hard muscular work with the same ration. The fat of milk, of butter, and of the fatty and oily materials in bread, corn meal, and other foods is like that of meat, stored as body-fat and used for fuel.

Vegetable foods, such as flour, meal, potatoes, and the like, contain a great deal of starch, sugar, and other carbohydrates. When these are taken into the body they are to some extent converted into fats, but their main use seems to be to serve for fuel. In serving as fuel the carbohydrates protect the fats and protein from being consumed. In like manner the fats may protect protein from consumption.

In short, the nitrogenous compounds of muscle, tendon, bone, and other parts of the framework of the body and of the blood are

made of the protein of the food. We get the fat of our bodies not only from the fats but from the protein, and probably from the carbohydrates, starch, sugar, etc., of our food. Other animals, dogs, sheep, swine, and geese, transform carbohydrates into fats, and there is every reason to believe that man is endowed with the same faculty. We use all these classes of nutrients, protein, fats, and carbohydrates, as sources of warmth and muscular strength. Our bodies, when they are in a healthy condition, contain a reserve of protein and fat which is drawn upon if food is lacking, or if there is extra muscular work to be done or extra cold to be endured. And whether the food supply is rightly adapted to the demands of the body or not, its tissues are continually consumed to supply its wants and are as constantly rebuilt from the food. The old notion that the whole body is made over once in seven years is wrong, however. Some parts are used up and renewed very rapidly, others very slowly. Such, at any rate, are the teachings of the most careful research as they are understood by the investigators who seem best qualified to judge.

ADAPTATION OF THE DIET TO THE DEMANDS OF THE BODY.

THE further details of the ways in which food is used in nutrition will naturally come in with the explanations in succeeding articles. But there are one or two more points which perhaps I ought to speak of now. One is, that the body requires a proper supply of each of the different kinds of nutrients for healthful nourishment. The proper supply of neither can be cut off without injury.

The protein can, to be sure, do some of the work of the fats and the carbohydrates. In the lack of plenty of vegetable food to furnish starch and sugar, for instance, we may get on pretty well for a while with meat, which has no carbohydrates, the protein and fat of the meat taking their place as fuel. The Laplanders and Esquimaux have extremely little vegetable food and consume enormous quantities of meat, and especially of fat meat, blubber, and what not. But their diet is hardly adapted to either the wants or the digestive apparatus of people of temperate climates. Ordinary people need considerable carbohydrates, and no amount of protein can fully supply their place.

But while the protein can to some extent serve in place of the carbohydrates and fats, these latter cannot replace the protein. The Esquimaux can live on meat, but neither men nor other animals can long thrive upon a diet of fat, or sugar, or starch without protein. The reason is that protein has a kind of work to do in building up the muscle, tendon, and

other tissues which the fats and carbohydrates cannot perform. Hence, we must have a certain amount of protein in our food or our bodies will suffer for the lack of it, and the more work there is to do, the greater the wear and tear of muscle and tendon, the more liberal must be the supply of protein as well as of other nutrients.

The effect of one-sided diet is very well illustrated in some experiments by Professor Ranke. They were made in the respiration apparatus at Munich, and belonged to the series of which I have already spoken. After he had studied the changes that went on in his body when fasting, he proposed to himself these questions:

What will be the effect of a diet of protein with very little fat and no carbohydrates on the one hand, and of a diet of fats and carbohydrates without protein on the other? In other words, how will the composition of the body be affected by food rich in protein and containing little else, and how will the store of fat and protein be altered by leaving the protein out of the food and living on the other nutrients?

For the diet of protein, he took lean meat, with butter and a little salt, essentially the same diet as was used by the student in the experiment described above. He had found himself able to eat 2000 grams of the lean meat in the course of the day, but in this experiment, which lasted 24 hours, he ate only 1833 grams (about 4 pounds) of meat and with it 70 grams of fat, 30 grams of salt, and 3371 grams (nearly 3 quarts) of water. Without going into the details, suffice it to say, that, according to Professor Ranke's calculations, his body lost 15.1 grams of fat and at the same time gained 113 grams of protein during the day of the experiment. In the other experiment, which likewise continued for 24 hours, the food consisted of 150 grams of fat, 300 grams of starch, and 100 grams of sugar, an even less appetizing mixture perhaps than the lean meat and butter for an exclusive diet, but yet one which, if put together with proper culinary skill, makes a cake that can be swallowed. This time he lost 51 grams of protein and gained 91.5 grams of fat.

The results of these two experiments may be recapitulated thus:

| On the diet consisting chiefly of | The body |
|--|---|
| Protein (lean meat, etc.), | gained protein (muscle, etc.) and lost fat. |
| Fats and carbohydrates (starch and sugar), | lost protein and gained fat. |

This is just what we might expect. But it is interesting to have the facts and figures to

show exactly what did take place, and other experiments make it safe to say that if either the quantities of food or the condition of Professor Ranke's body had been different, the results would have been different also. Thus in the first experiment if he had eaten less meat he would have stored less protein; indeed, with a small enough ration he would have lost both protein and fat, and it seems probable that if he had not been a rather fat person he would not have lost fat so readily on the protein diet.

Experiments confirm and to some extent explain the fact so well attested by general experience, that a mixed diet is best for ordinary people in health. Professor Ranke found that when he did no muscular labor, his body neither gained nor lost; that, in other words, he just about "held his own" with food, containing per day:

| <i>Protein.</i> | <i>Fats.</i> | <i>Carbohydrates.</i> |
|---------------------|--------------|-----------------------|
| 100 grams (3.5 oz.) | 100 grams | 240 grams (8.5 oz.) |

Professor Voit estimates as a fair allowance for a laboring-man doing a moderate amount of muscular work:

| <i>Protein.</i> | <i>Fats.</i> | <i>Carbohydrates.</i> |
|---------------------|------------------|-----------------------|
| 118 grams (4.2 oz.) | 56 grams (2 oz.) | 500 grams (17.6 oz.) |

For reasons to be given later, I think that to fairly meet the demand of the average American laboring-man (I mean the man whose labor is done with his muscles; brain-workers who have little muscular exercise need less food, I suppose) a more liberal allowance than Voit makes for laboring-men in Germany is needed. The American "working-man" is better paid, has more and better food, and does more work than his European brother. I should be inclined to quantities more like the following for the nutrients in the daily food of an average man doing manual work:

| | <i>Protein.</i> | <i>Fats.</i> | <i>Carbohydrates.</i> |
|-------------------|--------------------|--------------|-----------------------|
| For moderate work | 125 grs. (4.4 oz.) | 125 grs. | 400 grs. (14.4 oz.) |
| For hard work | 150 grs. (5.2 oz.) | 150 grs. | 400 grs. |

Men at very severe work may often need much more than the most liberal of these rations allows, while men, and especially women, of sedentary habits and elderly people are believed to usually require considerably less than the smallest figures indicate.

Statistics collected in the United States imply that the quantity of food consumed by many people whose occupations involve only light muscular labor approaches very near to the largest of these standards, and often considerably exceeds it. Indeed, a large array of facts lately gathered very strongly support the teaching of physicians that the failure to fit the food to the demands of the body, and especially the excessive consumption of cer-

tain kinds of food, are the sources of untold injury to health and happiness. But I am getting ahead of my subject.

THE COST AND VALUE OF ABSTRACT RESEARCH.

ONE can hardly realize, until he has found out by personal experience, the amount of labor, care, and patience, as well as learning and skill, that are required for such investigations as these I have described.

Professor Voit tells us that he has often worked with a servant three or four hours each day during an experiment in simply preparing the meat to be used for the food, in freeing it from fat and connective tissues so as to have as nearly pure protein as possible. In describing a series of experiments he says, "We give only the more important observations, in order to enable the reader to judge of the correctness of our conclusions, and omit the details of the analyses, which would swell the article too much." The article fills 115 royal octavo pages and is only one of scores by this one experimenter and his immediate associates.

At the agricultural experiment station at Weende, Germany, where the celebrated feeding-trials by Henneberg, Stohmann, and others with domestic animals were conducted, one of the assistants once told me a bit of experience with the respiration apparatus. As the result of a long series of observations, it appeared that something was out of order. What the trouble was Professor Henneberg could not find out. One day he happened to hear some one speak of the loss of weight of coal when exposed to the air. It occurred to him that a little coal-tar or some similar material, I have forgotten exactly what it was, had been used in the interior of the apparatus, and that perhaps this, like coal, might undergo such chemical changes as to develop gases and cause the trouble. This proved to be the case. The gentleman who related the incident added, "We have been at work now six years with the respiration apparatus and think we have just got where we can obtain satisfactory results with it." There is a popular idea that the results of scientific discovery, at least such as are most useful to people at large, can be turned out like pig-iron or cotton cloth,—so much in a given time, and with no great labor. Nothing could be more contrary to the facts.

To many people, a large part of the research made in the lines of which I have been speaking would appear so abstract and theoretical as to have but very little "practical" use. But as a matter of fact, the very things that seem most abstruse are of fundamental importance in the solution of the weightiest

problems of chemistry, physiology, hygiene, and social science. In this practical, pushing country of ours, especially, the idea is current that the profoundest studies, whether in physical science or in other departments of human knowledge, are very appropriate and ornamental for philosophers and for institutions devoted to abstract research, but not of much account for ordinary use. Coupled with this is the notion that our higher educational institutions should be places for the teaching of things already known, and that it is not particularly necessary for them to engage in the discovery of new truth. The more rapidly these impressions are done away with, and the more generally and generously abstract research in all departments of knowledge is cultivated, the better it will be for our thought and for our morals, and the sooner shall we get the information that will most help common folks in the ordinary struggles of daily life.

Is it not a significant fact that when we come to the study of even so preëminently plain and practical a subject as the food question, one which affects as many people, and affects them as seriously in health and purse if not in morals, as any of the great problems that are agitating the thought of the time, we must seek the fundamental data of our studies in the learned and profound research of foreign universities?

THE SOURCES OF INTELLECTUAL ENERGY.—
PHOSPHORUS AND THOUGHT.—FISH AS
BRAIN-FOOD.

THAT the labor of the brain is just as dependent upon food and the substances formed from it in the body as the labor of the hands, there is hardly room for doubt, but just what chemical elements or compounds, if any, are more concerned than others in mental or nervous exercise is a problem yet unsolved.

A great many people have the idea that thought is especially dependent upon phosphorus, and coupled with this is the widespread belief that the flesh of fish is particularly rich in phosphorus, and is hence especially valuable for brain-food.

The theory that connects thought with phosphorus more than with other elements appears to rest upon the fact that certain compounds, *protagon*, *lecithin*, etc., which contain phosphorus and are called *phosphorized fats*, are more abundant in the brain and nerves than in other parts of the body. From this it has been inferred that mental effort and nervous excitement involve the using up of large amounts of these substances, and that hence phosphorus compounds ought to be especially good for people who have much intel-

lectual work to do or are subject to great nervous strain. In support of this it has been claimed that brain-work increases the amount of phosphorus used up in the body and given off by it, just as muscular work increases the quantity of carbon burned and excreted.

But the compounds that make up the brain and nerves consist of the same elements as those in other organs, though the proportions are different; the phosphorized fats occur in other parts of the body as well as in the brain; *cerebrin*, a compound especially characteristic of the brain, contains no phosphorus; and the most careful experimenting has thus far failed to establish any definite connection between the amounts of intellectual work done and phosphorus excreted.

The value of phosphorus as food for the brain and nerves is frequently and strongly advocated in advertisements of medicines and medicinal foods containing it, and these are largely prescribed by the most eminent members of the medical profession, whose wisdom in so doing I by no means presume to question. But the theory that phosphorus has more to do, or is more necessary than carbon or nitrogen or other elements, in the production of intellectual energy is one to which I have never heard a physiological chemist of repute express his adherence, and in the writings of the experimental physiologists whose opinions are most valued by their fellow-specialists it is conspicuous by its absence.

The history of the theories of the connection between phosphorus and thought and of the value of fish as food for the brain has some rather curious phases.

Few utterances of modern writers have had such a world-wide currency as the expression, "*Ohne Phosphor kein Gedanke*" ("Without phosphorus, no thought"). One meets it everywhere and with it the notion, though generally in very crude form, that thought is somehow produced by phosphorus. A German gentleman of great intelligence told me he had often seen people who supposed that thought was accompanied by something in the brain akin to phosphorescence, like the glow of a phosphorus match in the dark. I have been led to think that the phrase has done more than anything else to spread the idea, though the idea could hardly have become so prevalent if there were not something to nourish it. What that something is I do not know, unless it be the natural query in every mind which the theory seems to answer. The expression has been attributed to various authors. An article in the last edition of the "*Encyclopædia Britannica*" credits it to Büchner. It is due, I believe, to Moleschott, and occurs in his "*Lehre der Nahrungsmittel*" ("Doctrine of Foods").

Of the early leaders of the movement which is sometimes called Materialism and which has so greatly influenced the thought of our time, Moleschott, Vogt, and Büchner were among the most prominent. Forty years or so ago, Moleschott was a *privat docent*—tutor, we should call it—in the University of Heidelberg, and an aspirant for higher academical honors. He was a man of ability as an investigator and writer. His genius was manifested in a controversy with Liebig in which he gained no little repute, and in other writings in which his views were set forth not only with remarkable force, but in a way which was particularly irritating to the metaphysicians and especially to the theologians of the more orthodox way of thinking. Heidelberg at that time was not so liberal in its theology as it has since become, and — I give the account as it was given me by one of the professors now there — young Moleschott's heterodoxy sufficed to deprive him of the liberty of teaching in the university and, as a not unnatural consequence, obtained for him a call to a professorship in another university, that of Zurich in Switzerland. In course of time he was called to Italy, where, as Professor of Physiology in the University of Turin, and later in the University of Rome, he has achieved still greater fame in science, and has also played an important rôle in statesmanship, both as the holder of a ministerial portfolio and as senator of Italy.

I remember very well a remark regarding his famous expression just referred to, which was made to me by Professor Moleschott in the course of a conversation not many years ago. It accords so well with what he had said in print that I think it will be no breach of confidence to mention it here. Remembering the suggestion of another well-known physiologist, that he had used it simply to illustrate and give point to the doctrine that thought and other mental operations are a function of matter, and thus stir up his ultra-conservative opponents, excite discussion, and propagate his tenets, I asked him what led him to make the statement in that form. He replied that of course he did not mean that intellectual energy was specifically dependent upon the consumption of phosphorus (indeed, that was clearly set forth in his writings at the time), and added with a smile, "Did you ever read —?" referring to an Italian book on the use of language. I was forced to confess that I had not, to which he replied, "There is a great deal in the way of putting things."

The saying served its purpose wonderfully even if, in its circulation, a shade of meaning has been added to it which it was not intended to convey. Not every man can penetrate to

the depths of human sentiment and coin from the common thought that is gathered there a phrase which will pass current everywhere and carry a doctrine with it. Like Grant's "Let us have peace" and Napoleon's "Providence is on the side of the strongest battalions," Moleschott's "Ohne Phosphor kein Gedanke" was a scintillation of genius.

If a current story is true, the idea that fish is especially good for brain-food can be traced to the elder Agassiz, though, for aught I know, it may be older. The story is that, years ago, Agassiz, who was then in the zenith of his fame and whose persuasive skill was scarcely inferior to his scientific genius, made an address in Massachusetts in behalf of a fish commission, and, with other considerations in its favor, urged that fish was very valuable for brain-food and that fish culture was hence peculiarly demanded by the marked intellectual activity of the people of that State. It would be superfluous to add that since that time fish culture has not languished in Massachusetts.

A gentleman well known in American science tells me that he once asked Agassiz what led him to this idea about fish as food, and that he replied, "Dumas [the French chemist] once suggested to me that fish contained considerable phosphorus and might on that account be especially good for food, and you know the old saying, 'Without phosphorus, no thought.' I simply put the two together."

Later, Mark Twain took up the idea and expressed it as follows (in "The Galaxy"):

"Young Author.—'Yes, Agassiz *does* recommend authors to eat fish, because the phosphorus in it makes brains. So far you are correct. But I cannot help you to a decision about the amount you need to eat—at least, with certainty. If the specimen composition you send is about your fair, usual average, I should judge that perhaps a couple of whales would be all you would want for the present. Not the largest kind, but simply good middling-sized whales.'"

As a vehicle for carrying the idea everywhere and "keeping it before the people" the efficiency of Mark Twain's joke was superlative. And aside from the intrinsic self-propagating power of the combination of joke and theory there was the widespread notion that phosphorus is the thought-producing element to help it. It would be hard to find conditions more favorable for the spread of a theory than were thus provided for this one of fish as nutriment for the brain. Coupled with the notion that phosphorus is the specific thought-element, it has coursed around the world.

Mr. E. G. Blackford, Fish Commissioner of New York and, I understand, the largest dealer in fish on this side of the Atlantic, assures me

of his belief that the theory materially increases the demand for fish as food. I have heard the same from other fish dealers, who say, "Why, you know fish is good brain-food." Indeed, it is really amusing, if one takes the trouble to notice, how many people will use the same expression, or one very much like it, if the subject is suggested. The theory is squarely adopted by some very prominent writers on foods, and is sometimes taught in schools. The Rev. Ram Chandra Bose, well known in Europe and America as one of the most learned of the Hindu converts to Christianity, tells me that if one were to "visit any of the great colleges in Calcutta and put to its advanced pupils the question, 'Why are the Bengalese intellectually superior to the other races of India?' the reply would be, 'Because they eat fish.' The belief that fish is rich in phosphorus, and hence serves to strengthen the brain more than other kinds of food do, is current among educated natives and their English teachers."

Even if fish were richer in phosphorus than meats or other food-materials this would not establish its superiority for the nutrition of the brain or the production of intellectual energy. But there is no proof of any especial abundance of phosphorus in fish. On the contrary, an extended series of analyses in this laboratory have revealed proportions of phosphorus in the flesh of our ordinary food fishes differing in no important degree from those which have been found to occur in the flesh of the other animals used for the food of man.

Perhaps some of the readers of this will put me down for an iconoclast, as did a most highly esteemed friend, who bade me, and with all candor and seriousness, to beware of thus ruthlessly attempting to uproot an old and important belief. But possibly they will have the charity to leave me a humble place in their consideration if I add that there is, after all, a way in which fish may make a very useful part of the diet of brain-workers.

Physiologists tell us that the way to provide for the welfare of the brain is to see that the rest of the body is in good order, that, in other words, the old proverb of "a sound mind in a sound body" is sound doctrine. And they are getting to tell us further that one way in which brain-work is hindered is by bad dietary habits, as, for instance, overloading the digestive organs by taking too much food. Of the vice of overeating (a vice which we Americans by no means monopolize) a considerable part, in this country at least, and I think in England and among well-to-do people on the Continent of Europe also, is the vice of

fat-eating. We are a race of fat-eaters. If any one doubts this, I think the statistics to be shown in a succeeding article will convince him, unless he is ready to deny the practically unanimous testimony of such facts as I have been able to gather. It comes about very naturally and is really due to the fertility of our soil, the consequent abundance of food, and the toothsome-ness of food-materials rich in fatty matters. The result of this is that the quantity of fat in the average American's dietary is very large indeed, mainly because of the large amounts of meats, butter, and lard consumed, and is far in excess of the demands of his body, unless he is engaged in very severe muscular work or exposed to extreme cold, or both. For people with sedentary occupations, including the majority of brain-workers, this simply means charging the organism with the burden of getting rid of an excess of material. This excess, the physiologists and physicians assure us, is detrimental.

If the reader will take the trouble to look at Diagram III. of the previous article of this series, he will see that the flesh of fish contains less fat than ordinary meats. Some kinds, like salmon, mackerel, white-fish, and shad, are quite fat, but the flesh of cod, haddock, bass, blue-fish, perch, flounder, indeed the majority of our most common food fishes, has extremely little of fatty and oily matters.

Now it seems to me very reasonable to assume that brain-workers and other people who do not have a great deal of muscular exercise may very advantageously substitute fish in the place of a portion of the meat which they would otherwise consume. I am very well aware that such hygienic advice might come more appropriately from a physician than from a chemist, and am therefore glad to be able to quote from no less an authority than Sir Henry Thompson, who urges "the value of fish to the brain-worker" on the ground that it "contains, in smaller proportion than meat, those materials which, taken abundantly, demand much physical labor for their complete consumption, and which, without this, produce an unhealthy condition of body, more or less incompatible with the easy and active exercise of the functions of the brain."

Perhaps I ought to add that the studies of the constitution of the flesh of fish in this laboratory, referred to above, as well as similar investigations elsewhere, show that, so far as the nutritive qualities are concerned, the only considerable difference between fish and ordinary meats is in the proportions of oily and fatty matters and water. The flesh of the fish has water where meats have fat.